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ABSTRACT

One of a series of training manuals prepared for enlisted personnel in the Navy and Naval Reserve, this self-study package provides subject matter that relates directly to the tasks required of the Construction Electrician, which include abilities to install, operate, service, and overhaul electric generating and distribution systems and wire communications systems; and control the activities of individuals and crews who string, install, and repair interior, overhead, and underground wires and cables, and attach and service units, such as transformers, switchboards, motors, and controllers. Contents include a 15-chapter text followed by a subject index and the associated nonresident career course (12 reading assignments and technical questions based upon each occupational standard in the respective assignment.) Chapter headings are (1) Meet the Construction Electrician, (2) Safety, (3) Blueprints, Diagrams, and Schematics, (4) Special Tools, (5) Test Equipment, (6) Control and Protective Equipment, (7) Shopwork, (8) Interior Wiring, (9) Central Power Stations, (10) Overhead Power Distribution, (12) Communications Systems, (13) Telephone Cable Splicing, (14) Administration, and (15) Basic Electronic Components and Circuits. The appendix includes the U.S. customary and metric system units of measurement. (HD)

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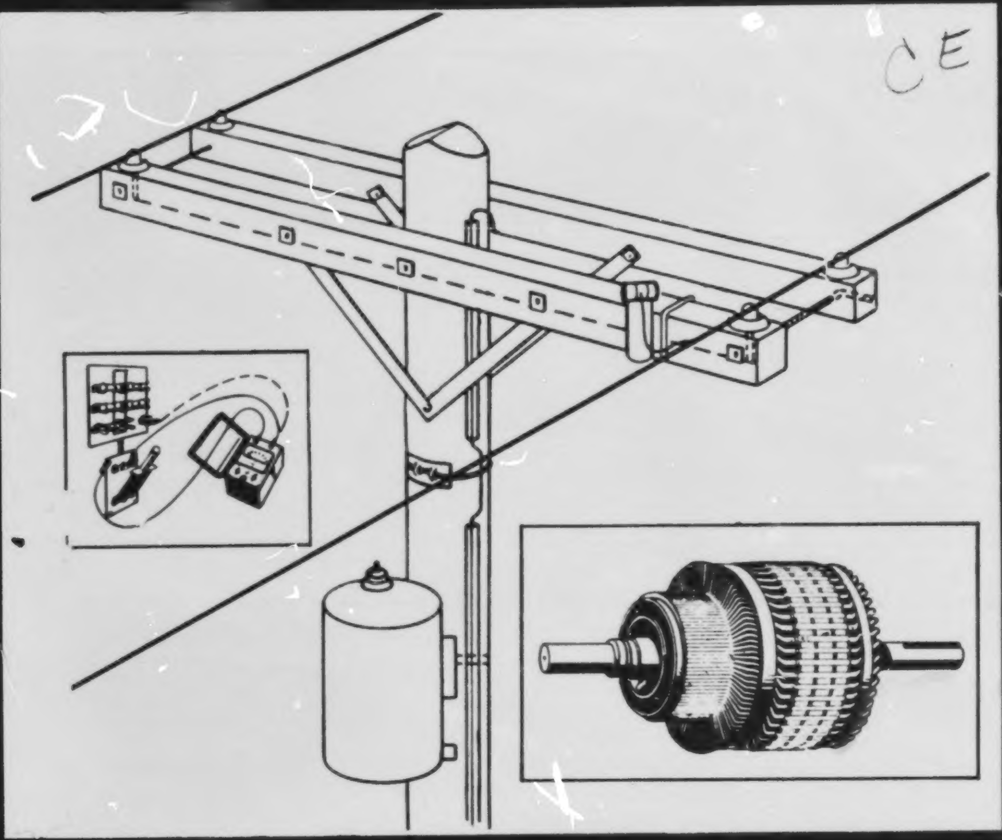

CE

CONSTRUCTION ELECTRICIAN 3 & 2

NAVAL EDUCATION AND TRAINING COMMAND

RATE TRAINING MANUAL
AND NONRESIDENT CAREER COURSE

NAVEDTRA 10636-H

CE 008 627

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PREFACE

The ultimate purpose of training naval personnel is to produce a combatant Navy which can ensure victory at sea. A consequence of the quality of training given them is their superior state of readiness. Its result is a victorious Navy.

This Rate Training Manual and Nonresident Career Course (RTM/NRCC) form a self-study package that will enable ambitious Construction Electricians to help themselves fulfill the rating. Among these requirements are the abilities to install, operate, service, and overhaul electric generating and distribution system and wire communications system; and control the activities of individuals and crews who string, install, and repair interior, overhead, and underground wires and cables, and attach and service units, such as transformers, switchboards, motors, and controllers.

Designed for individual study and not formal classroom instruction, the RTM provides subject matter that relates directly to the tasks required of the Construction Electrician. The NRCC provides the usual way of satisfying the requirements for completing the RTM.

The set of assignments in the NRCC includes learning objectives and supporting items designed to lead students through the RTM.

This RTM/NRCC was prepared by the Naval Education and Training Program Development Center, Pensacola, Florida for the Chief of Naval Education and Training. Technical assistance was provided by the Civil Engineer Support Office, NCBC Port Hueneme, California, the Naval Construction Training Center, Port Hueneme, California; and the Naval Construction Training Center, Gulfport, Mississippi.

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THE UNITED STATES NAVY

GUARDIAN OF OUR COUNTRY

The United States Navy is responsible for maintaining control of the sea and is a ready force on watch at home and overseas, capable of strong action to preserve the peace or of instant offensive action to win in war.

It is upon the maintenance of this control that our country's glorious future depends; the United States Navy exists to make it so.

WE SERVE WITH HONOR

Tradition, valor, and victory are the Navy's heritage from the past. To these may be added dedication, discipline, and vigilance as the watchwords of the present and the future.

At home or on distant stations we serve with pride, confident in the respect of our country, our shipmates, and our families.

Our responsibilities sober us; our adversities strengthen us.

Service to God and Country is our special privilege. We serve with honor.

THE FUTURE OF THE NAVY

The Navy will always employ new weapons, new techniques, and greater power to protect and defend the United States on the sea, under the sea, and in the air.

Now and in the future, control of the sea gives the United States her greatest advantage for the maintenance of peace and for victory in war.

Mobility, surprise, dispersal, and offensive power are the keynotes of the new Navy. The roots of the Navy lie in a strong belief in the future, in continued dedication to our tasks, and in reflection on our heritage from the past.

Never have our opportunities and our responsibilities been greater.

CONTENTS

CHAPTER Page

1. Meet the Construction Electrician 1
2. Safety 12
3. Blueprints, Diagrams, and Schematics 45
4. Special tools 61
5. Test equipment 88
6. Control and protective equipment 123
7. Shopwork 175
8. Interior wiring 235
9. Central power stations 270
10. Overhead power distribution 311
11. Underground power distribution 357
12. Communications systems 385
13. Telephone cable splicing 437
14. Administration 465
15. Basic electronic components and circuits 475

APPENDIX

I. The Metric System 507

INDEX 511

Nonresident Career Course follows Index

CREDITS

Source	Figures
Associated Research, Inc.	5-14 thru 5-20 5-30 thru 5-33
Daystrom Weston, Inc. Instruments Division	5-26 thru 5-28
Multi-Amp Corp.	5-29
Bacharach Instrument Co.	5-23 thru 5-25
TelaCable, Inc.	5-60 thru 5-63
Automatic Electric	6-31 thru 6-34
United Electric Controls	6-40
National Acme	6-43, 6-44, 6-46
Martindale Electric Co.	7-6
American Telephone & Telephone Co.	13-21

CHAPTER 1

MEET THE CONSTRUCTION ELECTRICIAN

Construction Electricians plan, supervise, and perform tasks required to install, operate, service, and overhaul electric generating and distribution systems and wire communications systems; control activities of individuals and crews who install and repair interior, overhead, and underground wires and cables; attach and service units, such as transformers, switchboards, motors , and controllers; and schedule and evaluate installation and operational routines.

As a CE you will probably be performing your assigned tasks while serving in a Naval Mobile Construction Battalion that is engaged in overseas construction. There you can expect to be in "B" company, which operates as a special construction company for battalion projects or as a rifle company in a combat situation. There is also a chance you could be assigned to an Amphibious Construction Battalion, either the one at Little Creek, Virginia or Coronado, California. Some CE's are assigned to Construction Battalion Maintenance Units. Their tasks concern maintenance of advanced bases. Other billets to which CE's are assigned include the CE school at Port Hueneme, California (for instructor duty), Naval Education and Training Program Development Center at Pensacola, Florida (for development of training publications and advancement examinations), and Public Works Departments at naval shore activities.

THE PUBLIC WORKS DEPARTMENT

When you are assigned to duty at a shore activity, either within the United States or overseas, you will most likely be assigned to the Public Works Department of the station. Most stations which have more than about 100 men and 15 or 20 buildings have a Public Works Department (which administers and maintains public works and utilities), except that in some localities Public Works Centers have been established. A Public Works Center performs the public works duties for a number of Navy activities in that vicinity.

The Public Works Department is headed by a Public Works Officer, who is an officer of the Civil Engineer Corps. The organization and staffing of the Department varies considerably, depending on the size, location, and mission of the activity. The larger Public Works Departments are generally divided into Administrative and Technical Divisions (Administrative, Engineering, Maintenance Control, and sometimes Housing) and Operating Divisions (Maintenance, Utilities, and Transportation). The Operating Divisions are usually headed by a CEC officer who has the title Shops Engineer. Smaller stations might have only three divisions: Administrative, Engineering, and Shops. The Shops Division usually has a Transportation Branch.

Some Public Works Departments, particularly at small, isolated stations, may be staffed entirely by military personnel, but most Public Works Departments, both in the United States and overseas, are staffed largely by civilians. The Administrative and Technical Divisions (except for Maintenance Control) are mainly staffed with civil servants classed as GS, or per annum, or white collar employees. The Operating Divisions are mainly staffed with civil servants classed as wage board, or per diem, or blue collar employees. Supervisory blue collar employees have titles such as (in ascending order of responsibility) snapper, head, leadingman, quarterman, and chief quarterman. Very large stations may also have master mechanics and foreman mechanics. At bases overseas, foreign nationals may be hired to work in the Public Works Department. They may be employed directly as a special category of civil servant, or they may be utilized as contract labor through the negotiation of a labor contract with the host government of the country involved.

DUTY WITHIN THE U.S.

As stated before, if you are assigned to shore activity within the U.S. you will most likely be assigned to Public Works; but this is not always the case. In areas where there is a large stable supply of manpower, most of the utilities work is done by blue collar employees. Therefore, you may be assigned to the master at arms force, special services, the salvage yard, the commissary, or to any of a great variety of jobs.

Your chances of working at your trade are much better in areas where there is a relative shortage of manpower. In these areas, you may expect to be assigned to the Utilities Division or the Maintenance and Utilities Branch of the Shops Division of a Public Works Department. Some Public Works Officers prefer to organize two separate lines of authority: one for civilians and one for the military personnel. Others prefer to integrate the civilians and military completely; in the latter case you may work beside a civilian and report to a CE1, who reports to a quarterman, who answers to the Shops Engineer, who is an officer. There are some activities which are staffed completely by military personnel because the mission is highly classified; if you are assigned to a station of this type you may expect to work within your rating.

DUTY AT OVERSEAS BASES

In general, you may expect to work in your trade if assigned to a shore activity outside the U.S. At smaller, relatively isolated stations the entire Public Works staff may be military personnel. At the larger activities you may expect to work with civil servants from the U.S., both white collar and blue collar, and with foreign nationals.

THE ENLISTED RATING STRUCTURE

The two main types of ratings in the present enlisted rating structure are general ratings and service ratings.

GENERAL RATINGS identify broad occupational fields of related duties and functions. Some general ratings include service ratings; others do not. Both Regular Navy and Naval Reserve personnel may hold general ratings.

An example of the General Rating is the Construction Electrician (CE) rating, which is a straight progression from Construction Recruit (CR) to Master Chief Utilitiesman (UTCM).

Construction Electrician

CR-CA-CN-CE3-CE2-CE1-CEC-CECS-UTCM

SERVICE RATINGS identify subdivisions or specialties within a general rating. Although service ratings can exist at any petty officer level, they are most common at the PO 3 and PO2 levels. Both Regular Navy and Naval Reserve personnel may hold service ratings.

OCCUPATIONAL STANDARDS

A most important step in developing your career is to acquire the skills that have been prescribed specifically for each paygrade of the CE rating. These skills, expressed in terms of task statements called occupational standards, are contained in the Manual of Navy Enlisted Manpower and Personnel Classifications and Occupational Standards, NAVPERS 18068-D. Other requirements, called naval standards, are not specifically rating oriented. These too are contained in NAVPERS 18068-D. Studying this rate training manual should help you meet the occupational standards for CE3 or CE2. Naval standards can be met by studying other training manuals which are named later in this chapter.

NAVY ENLISTED CLASSIFICATIONS

Associated with the Construction Electrician rating are Navy Enlisted Classifications (NEC's) which identify skills requiring more specific identification than is provided by rates and ratings, and which are not rating-wide requirements. NEC's are designed to facilitate management of manpower by identifying accurately billets and personnel. They help in distribution and detailing of personnel. The following NEC's may be earned by Construction Electricians:

1. SHORE-BASED POWERPLANT TECHNICIAN, CE-5632—He operates, services, and performs organizational and/or intermediate level maintenance on electrical systems of shore-based powerplants. This NEC is assigned only to personnel in pay grades E-5 through E-7 upon satisfactory completion of the applicable course.

2. CENTRAL OFFICE EXCHANGE TECHNICIAN, CE-5642—He installs, inspects, maintains, and performs organizational and/or intermediate level maintenance on automatic PBX or PAX telephone exchange equipment, including switchboards, dial selection mechanisms, and telephones; performs troubleshooting operations; performs necessary adjustments and replacements; cleans and adjusts contacts and adjusts contact clearances; tests circuits using spring tension gages, voltmeters, and ohmmeters; performs daily or periodic ground or insulation tests on switchboards. This NEC is assigned only to personnel E-5 through E-7 upon satisfactory completion of the applicable course.

3. CABLE SPLICING TECHNICIAN, CE-5644—He splices multiple conductor cables used in telephone and telegraph communications and electric-power transmission systems. This NEC is assigned only to personnel E-5 through E-7 upon satisfactory completion of the applicable course.

4. CONSTRUCTION PLANNER AND ESTIMATOR SPECIALIST, EA-5515—He plans and estimates material, manpower, and equipment requirements for various construction jobs; performs scheduling, procurement, production control, and management reporting of construction projects. This NEC is assigned not only to CE's, but also to EA's, BU's, UT's, and SW's in pay grades E-5 through E-7, who are graduates of the course, Engineering Aids/Planning and Estimating.

5. ADVANCED UNDERWATER CONSTRUCTION TECHNICIAN, BU-5931—He performs underwater construction operations using all types of underwater equipment and tools. In doing this, he plans and supervises simple underwater construction operations; estimates manpower and equipment requirements for various underwater construction projects; inspects material condition, monitors general readiness, diagnoses improper operating procedures and equipment failures. This NEC is available to SEABEE personnel in paygrades E-5 through E-9.

6. BASIC UNDERWATER CONSTRUCTION TECHNICIAN, BU-5932—He performs underwater construction operations using common underwater tools, equipment, and materials. In doing this, he performs duties related to underwater construction blasting; component emplacement and assembly; underwater cutting and welding; seafloor surveying; foundations and anchor emplacement; rigging; cable laying and splicing; and system testing. This NEC is available to SEABEE personnel who are graduates of the Basic Underwater Construction Technician course.

7. SAFETY INSPECTOR, SW-6021—He organizes and supervises the operation of the safety department. In doing this, he investigates accidents, analyzes accidents and problem areas, and recommend methods to decrease frequency and/or eliminate accidents; collects data to ascertain accident trends; inspects project sites, grounds, buildings and machinery to isolate hazards to life, health, and equipment; conducts safety education campaigns by preparing and/or distributing literature, posters, charts, and displays; organizes and directs the safety committee; directs placement of traffic control signs and devices. This NEC is assigned to SEABEE personnel in paygrades E-6 and E-7 who satisfactorily complete two courses: Basics of Occupational Safety and Health (OSH-300) and Occupational Safety and Health Standards of the Construction Industry (OSH-220).

8. NUCLEAR POWERPLANT OPERATOR, 3391—He operates, maintains, and performs organizational level maintenance on nonpropulsive nuclear powerplants and radioisotope power devices, as an Electrical, Mechanical, Instrument or Health Physics/Plant Chemistry Specialist. This NEC is normally assigned to CE's in pay grades E-4 through E-7 who are graduates of the course, Nuclear Powerplant Operators, which is offered at the Naval Nuclear Power Unit at Fort Belvoir, Virginia. NEC 3391 is also available to personnel in the UT, EO, CM, SW, and HM ratings.

THE NAVY ENLISTED ADVANCEMENT SYSTEM

Many of the rewards of Navy life are earned through the advancement system. The basic ideas behind the system have remained stable for many years but specific portions may change rather rapidly. It is important that you know the system and follow changes carefully. BUPERS Notice 1418 will normally keep you up to date.

The normal system of advancement may be easier to understand if it is broken into two parts:

1. Those requirements that must be met before you may be considered for advancement.

2. Those factors that actually determine whether or not you will be advanced.

QUALIFYING FOR ADVANCEMENT

In general, to QUALIFY (be considered) for advancement, you must first:

1. Have a certain amount of time in pay grade.

2. Demonstrate knowledge of material in your mandatory Rate Training Manuals by achieving a suitable score on your Command's test, by successfully completing the appropriate Nonresident Career Courses (NRCC's) or, in some cases, by successfully completing an appropriate Navy School.

3. Demonstrate the ability to perform all the skill requirements listed on the Record of Practical Factors, NAVEDTRA 1414/1.

4. Be recommended by your commanding officer.

5. For petty officer third and second candidates ONLY, demonstrate knowledge of military subjects by passing a locally administered MILITARY/LEADERSHIP examination based on the naval standards (from NAVPERS 18068-D).

6. Demonstrate knowledge of the skill requirements for your rate by passing a Navywide advancement examination based on the occupational standards (from NAVPERS 18068-D).

Figure 1-1 gives a detailed view of the requirements for advancement of active duty personnel; figure 1-2 gives this view for advancement of inactive duty personnel. Remember that the naval and occupational standards can change. Check with your division officer or training officer to be sure that you have the most recent standards.

If you meet all of the above requirements satisfactorily, you become a member of the group from which advancements will be made.

WHO WILL BE ADVANCED?

Advancement is not automatic. Meeting all of the requirements makes you eligible but does not guarantee your advancement. Some of the factors that determine which persons, out of all of those QUALIFIED, will actually be advanced in rate are: the score made on the advancement examination, the length of time in service, the performance marks earned, and the number of vacancies being filled in a given rate.

If the number of vacancies in a given rate exceeds the number of qualified personnel, then ALL of those qualified will be advanced. More often, the number of qualified people exceeds the vacancies. When this happens, the Navy has devised a procedure for advancing those who are BEST qualified. This procedure is based on combining three personnel evaluation systems:

Merit rating system (Annual evaluation and C.O. recommendation).

Personnel testing system (Advancement examination score—with some credit for passing previous advancement exams).

Longevity (seniority) system (Time in Rate and Time in Service).

Simply, credit is given an individual in three areas: performance, knowledge, and seniority. A composite known as the final multiple score is generated from these three factors. All of the qualified candidates from a given advancement examination population are then placed on one list, based on this composite figure, the highest achiever first, and so on down to the last qualified person in the population. For candidates for E-4, E-5, and E-6, advancement authorizations are then issued, beginning at the top of the list, for the number of persons needed to fill the existing vacancies. Candidates for E-7 whose final multiple scores are high enough will be designated PASS SELBD ELIG (Pass Selection Board Eligible). This means that their names will be placed before the Chief Petty Officer Selection Board, a BUPERS board charged with considering all so-designated eligible candidates for advancement to CPO. Advancement authorizations for those being advanced to CPO are issued by this board.

Who, then, are the individuals who are advanced? Basically, they are the ones who achieved the most in preparing for advancement. They were not content to just qualify; they went the extra mile in their training, and through that training and their work experience they

REQUIREMENTS*	E1 to E2	E2 to E3	# E3 to E4	# E4 to E5	E5 to E6	†E6 to E7	†E7 to E8	†E8 to E9
SERVICE	4 mos. service- or completion of Recruit Training.	8 mos. as E-2.	6 mos. as E-3. 2 years time in service.	12 mos. as E-4. 3 years time in service.	24 mos. as E-5. 6 years time in service.	36 mos. as E-6. 9 years time in service.	36 mos. as E-7. 8 of 12 years time in service must be enlisted.	36 mos. as E-8. 10 of 15 years time in service must be enlisted.
SCHOOL	Recruit Training. (C.O. may advance up to 10% of graduating class.)	▨	Class A for PR3, DT3, IS3, AME3, HM3, PN3, FTB3, MT3.	▨	▨	Navy School for AGC, MUC, MNC. ††		
PRACTICAL FACTORS	Locally prepared check-offs.	Record of Practical Factors, NAVEDTRA 1414/1, must be completed for E-3 and all PO advancements.						
PERFORMANCE TEST	▨	▨	Specified ratings must complete applicable performance tests before taking examinations.				▨	▨
ENLISTED PERFORMANCE EVALUATION	As used by CO when approving advancement.		Counts toward performance factor credit in advancement multiple.					
EXAMINATIONS**	Locally prepared tests.	See below.	Navywide examinations required for all PO advancements.			Navywide selection board.		
RATE TRAINING MANUAL (INCLUDING MILITARY REQUIREMENTS)	▨	Required for E-3 and all PO advancements unless waived because of school completion, but need not be repeated if identical course has already been completed. See NAVEDTRA 10052 (current edition).					Nonresident career courses and recommended reading. See NAVEDTRA 10052 (current edition).	
AUTHORIZATION	Commanding Officer		NAVEDTRAPRODEVCEN					

* All advancements require commanding officer's recommendation.
† 3 years obligated service required for E-7, E-8, and E-9.
# Military leadership exam required for E-4 and E-5.
** For E-2 to E-3, NAVEDTRAPRODEVCEN exams or locally prepared tests may be used.
†† Waived for qualified EOD personnel.

Figure 1-1.—Active duty advancement requirements.

REQUIREMENTS *	E1 to E2	E2 to E3	E3 to E4	E4 to E5	E5 to E6	E6 to E7	E8	E9
TOTAL TIME IN GRADE	4 mos.	8 mos.	6 mos.	12 mos.	24 mos.	36 mos. with total 9 yrs service	36 mos. with total 12 yrs service	[illegible] mos. with total 15 yrs service
TOTAL TRAINING DUTY IN GRADE †	14 days	14 days	14 days	14 days	28 days	42 days	42 days	28 days
PERFORMANCE TESTS	▨	▨	Specified ratings must complete applicable performance tests before taking examination.					
DRILL PARTICIPATION	Satisfactory participation as a member of a drill unit in accordance with BUPERSINST 5400.42 series.							
PRACTICAL FACTORS (INCLUDING MILITARY REQUIREMENTS)	Record of Practical Factors, NavEdTra 1414/1, must be completed for all advancements.							
RATE TRAINING MANUAL (INCLUDING MILITARY REQUIREMENTS)	Completion of applicable course or courses must be entered in service record.							
EXAMINATION	Standard Exam		Standard Exam required for all PO advancements. Also pass Military Leadership Exam for E-4 and E-5.				Standard Exam, Selection Board.	
AUTHORIZATION	Commanding Officer		NAVEDTRAPRODEVCEN					

* Recommendation by commanding officer required for all advancements.
† Active duty periods may be substituted for training duty.

Figure 1-2.—Inactive duty advancement requirements.

developed greater skills, learned more, and accepted more responsibility.

While it cannot guarantee that any one person will be advanced, the advancement system does guarantee that all persons within a particular rate will compete equally for the vacancies that exist.

HOW TO PREPARE FOR ADVANCEMENT

What must you do to prepare for advancement? You must study the naval and occupational standards, demonstrate that you can perform required skills, study the required rate training manuals, and study other material that is required for advancement. To prepare for advancement, you will need to be familiar with (1) the Manual of Navy Enlisted Manpower and Personnel Classifications and Occupational Standards, (2) the Record of Practical Factors, (3) the Bibliography for Advancement Study, and (4) the applicable rate training manuals. The following sections describe each of these and give you some practical suggestions on how to use them in preparing for advancement.

Manual of Navy Enlisted Manpower and Personnel Classifications and Occupational Standards

The Manual of Navy Enlisted Manpower and Personnel Classifications and Occupational Standards, NAVPERS 18068-D, defines rates and ratings by describing the Navy's requirements for enlisted skills. The manual consists of two sections. The first section contains the occupational standards and naval standards that form the basis for what enlisted personnel are trained in and advanced upon. The second section contains the Navy Enlisted Classifications (NEC's) which were defined earlier in this chapter.

The naval standards contained in NAVPERS 18068-D express the minimum skills required of enlisted personnel which are not specifically rating oriented. For the most part they are stated as knowledge requirements because they represent basic things which should be known, and not necessarily done as a matter of routine. The occupational standards appear as task statements only since they define what enlisted personnel must do in their rate or rating. In other words, they are performance factors. The knowledge required to perform a task is inherent to the proper performance of the task.

Record of Practical Factors

Before you can take the Navywide examination for advancement, there must be an entry in your service record to show that you have met the naval and occupational standards for your rate and rating. The RECORD OF PRACTICAL FACTORS, NAVEDTRA 1414/1, is used for this purpose. Available for each rating, the form lists all performance factors, or task statements for the rating. As you demonstrate your ability to perform each factor, appropriate entries are made in the DATE and INITIALS columns. Space is provided on the form for entering additional performance factors or recording demonstrated proficiency in skills which are within the general scope of the rating but which are not identified as occupational standards.

Until completed, the NAVEDTRA 1414/1 is usually held by your division officer; after completion, it is forwarded to the personnel office for insertion in your service record. If you are transferred before qualifying in all performance factors, the incomplete form should be forwarded with your service record to your next duty station. You can save yourself a lot of trouble by making sure that this form actually is inserted in your service record before you are transferred. If the form is not in your service record, you may be required to start all over again and requalify in the performance factors which have already been checked off.

Bibliography for Advancement Study

The Bibliography for Advancement Study, NAVEDTRA 10052 (revised) is important to all enlisted personnel preparing for advancement. It lists the rate training manuals and other publications prescribed for use by naval personnel concerned with training and advancement examinations.

NAVEDTRA 10052 is revised and issued yearly by the Naval Education and Training Support Command. Each revised edition is identified by a letter following the number. When using this publication be sure that you have the most recent edition.

If extensive changes in standards occur in any rating between the annual revisions of NAVEDTRA 10052, a supplementary list of study material may be issued in the form of a BUPERS Notice. When you are preparing for advancement, check to see whether changes have been made in the standards for your rating. If so, look for a BUPERS Notice that supplements NAVEDTRA 10052 for your rating.

The required and recommended references are listed by pay grade in NAVEDTRA 10052. If you are working for advancement to third class, study the material that is listed for third class. If you are working for advancement to second class, study the material that is listed for second class; but remember that you are also responsible for the references listed at the third class level.

In using NAVEDTRA 10052 you will notice that some rate training manuals are marked with an asterisk (*). Any manual marked in this way is MANDATORY—that is, it must be completed at the indicated rate level before you can be eligible to take the servicewide examination for advancement. Each mandatory manual may be completed by (1) passing the appropriate nonresident career course that is based on the mandatory training manual; (2) passing locally prepared tests based on the information given in the training manual; or (3) in some cases, successfully completing an appropriate Navy school.

Do not overlook the section of NAVEDTRA 10052 which lists the required and recommended references relating to the naval standards. Personnel of ALL ratings must complete the mandatory military requirements training manual for the appropriate level before they can be eligible to advance.

The references in NAVEDTRA 10052 which are recommended but not mandatory should also be studied carefully. ALL references listed in NAVEDTRA 10052 may be used as source material for the written examinations, at the appropriate rate levels.

Rate Training Manuals

There are two general types of rate training manuals. RATING manuals (such as this one) are prepared for most enlisted ratings. A rating manual gives information that is directly related to the occupational qualifications of ONE rating. SUBJECT MATTER manuals or BASIC manuals give information that applies to more than one rating.

Rate training manuals are revised from time to time to keep them up to date technically. The revision of a rate training manual is identified by a letter following the NAVEDTRA number. You can tell whether any particular copy of a training manual is the latest edition by checking the NAVEDTRA number and the letter following this number in the most recent edition of List of Training Manuals and Correspondence Courses, NAVEDTRA 10061. (NAVEDTRA 10061 is actually a catalog that lists all current training manuals and correspondence courses; you will find this catalog useful in planning your study program.)

Each time a rate training manual is revised, it is brought into conformance with the official publications and directives on which it is based; but during the life of any edition, discrepancies between the manual and the official sources are almost certain to arise because of changes to the latter which are issued in the interim. In the performance of your duties, you should always refer to the appropriate official publication or directive. If the official source is listed in NAVEDTRA 10052, the Naval Education and Training Program Development Center uses it as a source of questions in preparing the fleetwide examinations for advancement. In case of discrepancy between any publications listed in NAVEDTRA 10052 for a given rate, the examination writers will use the most recent material.

Rate training manuals are designed to help you prepare for advancement. The following suggestions may help you to make the best use of this manual and other Navy training publications when you are preparing for advancement.

1. Look up the occupational standards for your rating before you study the training manual, and refer to them frequently as you study. Remember, you are studying the manual primarily in order to meet the standards.

2. Set up a regular study plan. It will probably be easier for you to stick to a schedule if you can plan to study at the same time each day. If possible, schedule your studying for a time of day when you will not have too many interruptions or distractions.

3. Before you begin to study any part of the manual intensively, become familiar with the entire book. Read the preface and the table of contents. Check through the index. Look at the appendixes. Thumb through the book without

any particular plan, looking at the illustrations and reading bits here and there as you see things that interest you.

4. Look at the training manual in more detail, to see how it is organized. Look at the table of contents again. Then, chapter by chapter, read the introduction, the headings, and the subheadings. This will give you a pretty clear picture of the scope and content of the book. As you look through the book in this way, ask yourself such questions as:

- What do I need to learn about this?

- What do I already know about this?

- How is this information related to information given in other chapters?

- How is this information related to the occupational standards?

5. When you have a general idea of what is in the training manual and how it is organized, fill in the details by intensive study. In each study period, try to cover a complete unit—it may be a chapter, a section of a chapter, or a subsection. The amount of material that you can cover at one time will vary. If you know the subject well, or if the material is easy, you can cover quite a lot at one time. Difficult or unfamiliar material will require more study time.

6. In studying any one unit—chapter, section, or subsection—write down the questions that occur to you. Many people find it helpful to make a written outline of the unit as they study, or at least to write down the most important ideas.

7. As you study, relate the information in the training manual to the knowledge you already have. When you read about a process, a skill, or a situation, try to see how this information ties in with your own past experience.

8. When you have finished studying a unit, take time out to see what you have learned. Look back over your notes and questions. Maybe some of your questions have been answered, but perhaps you still have some that are not answered. Without looking at the training manual, write down the main ideas that you have gotten from studying this unit. Don't just quote the book. If you can't give these ideas in your own words, the chances are that you have not really mastered the information.

9. Use nonresident career courses whenever you can. As mentioned before, completion of a mandatory rate training manual can be accomplished by passing an NRCC based on the rate training manual. You will probably find it helpful to take other NRCC's as well as those based on mandatory manuals. Taking an NRCC helps you to master the information given in the training manual, and also helps you see how much you have learned.

10. Think of your future as you study rate training manuals. You are working for advancement to third class or second class right now, but some day you will be working toward higher rates. Anything extra that you can learn now will help you both now and later.

SOURCES OF INFORMATION

One of the most useful things you can learn about a subject is how to find out more about it. No single publication can give you all the information you need to perform the duties of your rating. You should learn where to look for accurate, authoritative, up-to-date information on all subjects related to the naval standards and occupational standards of your rating.

Some publications are subject to change or revision from time to time—some at regular intervals, others as the need arises. When using any publication that is subject to change or revision, be sure that you have the latest edition. When using any publication that is kept current by means of changes, be sure you have a copy in which all official changes have been made. Studying canceled or obsolete information will not help you to do your work or to advance; it is likely to be a waste of time, and may even be seriously misleading.

GOVERNMENT PUBLICATIONS

There are various Government publications which you may find useful as sources of reference. A number of publications issued by the Naval Facilities Engineering Command (NAVFAC) which will be of interest to SEABEES are listed in the NAVFAC Documentation Index, NAVFAC P-349 (updated semiannually). A publications program is one of the principal communications media used by NAVFAC to provide a ready reference of current technical and administrative data for use by its subordinate units. NAVFAC publications are listed in alphabetical and numerical order in NAVFAC P-349; copies of NAVFAC P-349 may be obtained through proper channels from the U.S. Naval Publications and Forms Center, 5801 Tabor Avenue, Philadelphia, Pennsylvania 19120.

Some of the training publications that you will need to study or refer to as you prepare for advancement have already been mentioned in this chapter. Some additional publications that you may find useful are listed below.

Electrical Engineering, DM-4
Electric Power Distribution Systems Maintenance, MO-200
Advanced Base Electrical and Communication Systems, TP-PL-15

The Army publishes a number of technical manuals (TMs) relating to the field of the Construction Electrician. Among these are the following:

Electrical Power Transmission and Distribution, TM 5-765

Electrical Facilities, Substations, Repairs and Utilities, TM 5-680F
Electric Motor and Generator Repair, TM 5-764
Fundamentals of Telephony, TM 11-678

The National Bureau of Standards of the U.S. Department of Commerce publishes the National Electrical Safety Code as National Bureau of Standards Handbook H30. Section 1 of this work contains electrical definitions; section 9 contains rules covering methods of protective grounding. The remainder of the book consists of 5 parts, as follows:

Part 1.—Rules for the installation and maintenance of electrical supply stations.
Part 2.—Rules for the installation and maintenance of electric supply and communication lines.
Part 3.—Rules for the installation and maintenance of electric utilization equipment.
Part 4.—Rules for the operation of electric equipment and lines.
Part 5.—Rules for radio installations.

The Bureau of Standards issues from time to time a handbook which amends parts of Handbook H30. At the time of writing of this course, the latest amending handbook was Handbook 81, issued 1 November 1961, and containing a complete reissue of section 1 (definitions), section 9 (rules covering methods of protective grounding), and Part 2 (rules for the installation and maintenance of electric supply and communication lines).

Safety precautions applying to just about every type of construction are codified and issued by the Headquarters, Naval Material Command in Department of the Navy Safety Precautions for Shore Activities, NAVMAT P-5100.

Chapter 15 of NAVMAT P-5100 contains precautions which have particular application to electricity. General electrical precautions are contained in articles 1501 through 1503. Precautions relating to electrical equipment are given in articles 1510 through 1520. Article 1525 contains precautions to be observed when working on energized circuits. Precautions relating to line construction and distribution are in articles 1530 through 1535.

Many of the nonelectrical chapters of Safety Precautions for Shore Activities contain information of interest and concern to the Construction Electrician, such as chapter 3, "Materials Handling and Storage;" chapter 8, "Construction;" chapter 14, "Portable Tools;" and chapter 20, "Hazardous Materials."

You will also find safety precautions applicable to your rating in Naval Construction Force Safety Manual, COMCBPAC/COMCBLANT Instruction 5100.1 series.

MANUFACTURERS' MANUALS

When new equipment is procured by the Navy, it usually is accompanied by a manual of operating, maintenance, and installation instructions. These manuals should be kept readily available for reference. They describe in detail the procedures for installing, maintaining and operating a specific piece of equipment.

Study the manuals. Take care of them. Do not lose or damage them. When you are required to repair a piece of equipment, follow the manual's instructions carefully.

COMMERCIAL PUBLICATIONS

A wealth of information on electrical construction exists in various reports, pamphlets, handbooks, and textbooks prepared by manufacturers, trade associations, technical and professional societies and other sources. Much of this literature is available in station libraries, Public Works Departments, and battalion offices and libraries.

TRAINING FILMS

Training films available to naval personnel are a valuable source of supplementary information on many technical subjects. Training films are listed in the United States Navy Film Catalog, NAVAIR 10-1-777, published in July 1971. Copies may be ordered in accordance with the Navy Stock List of Forms and Publications, NAVSUP 2002. Supplements to the Film Catalog are issued periodically.

When selecting a film, note its date of issue listed in the Film Catalog. As you know, procedures sometimes change rapidly. Thus some films become obsolete rapidly. A film that is obsolete only in part may sometimes be shown effectively if, before or during its showing, procedures that have changed are pointed out to the viewers.

CHAPTER 2

SAFETY

All electrical systems are potential KILLERS. Personnel should be aware of the potential danger. CE's especially should have complete knowledge of the inherent and manmade electrical hazards because they WORK on electrical equipment or systems. But safety applies not only to electrical equipment or systems, but to the entire construction field and its hazards which are always present.

In this chapter, we will examine some of these hazards and provide proven ways of protecting yourself and others against them. By adhering to safe working practices, you will minimize danger to life and equipment. Furthermore, by learning first aid and how to apply it correctly, you may be able to save someone's life.

ACCIDENT PREVENTION

Accident prevention depends on your knowing the appropriate safety factors for a given hazardous condition, on your ability to recognize a condition as hazardous. Conditions change from job to job and from day to day on the same job, so you must be constantly alert to the possibility of new hazards. Whenever you observe a safety hazard, even though you may not be involved in the work being done, call it to the attention of a responsible person. Make a prompt report of any unusual condition, whether in a generating station, a substation, an underground or overhead cable system, or any electrical equipment. Unusual conditions are frequently the forerunners of a break in continuity of service, and they usually increase the hazard level. When they occur the best procedure is to take immediate protective steps, rather than wait until it is obvious that a hazard has developed.

ELECTRICAL SHOCK: CAUSES AND CONSEQUENCES

Most fatal electric shocks do not happen to the uninitiated—they happen to people who should know better. As a CE, carelessness in your work can sentence you to death by electrocution. Familiarity with the equipment tends to make you forget the little precautions taught in trade school.

Unfortunately, it is impossible to bring the dead back to life or change the results of the accident; that is why it is necessary, even at the risk of monotony, to constantly stress or even preach SAFETY. It may make you think twice before taking that last chance.

Most of us are apt to remember only the most important safety precautions, but how many of us stop to think of the small details that really ENSURE safety? Also, how many of us realize it is the current, not the voltage, that is lethal?

Although the sign CAUTION—HIGH VOLTAGE serves as a reminder to keep hands off, don't forget that an electric shock from 10,000 volts is no more deadly than a shock from ordinary 115-volt house current. Industrial equipment using as little as 42 volts of direct current has been fatal (30 volts a-c is considered hazardous). CURRENT, NOT VOLTAGE, IS THE LETHAL AGENT.

The seriousness of an electric shock depends upon the magnitude of the current flow in the victim. Current flow, in turn, depends upon the electrical resistance of the circuit path through the victim's body. This can vary considerably depending upon the degree of contact and the skin resistance at the time of contact.

We are all aware of the presence of moist skin caused by perspiration on a hot day, but few of us think about the sudden moistening of the skin when we are frightened or startled. The unexpected discharge of a capacitor or the inadvertent shorting of a voltage point when troubleshooting often will startle the technician, make him jump, and at the same time bring on a momentary cold sweat. Such reactions are not uncommon, and obviously they set up a shocking situation.

Although this may be considered an extreme case, it does illustrate how an individual's resistance can vary considerably from minute to minute, depending upon his emotional state at the instant of contact. Skin resistances of a few hundred ohms when wet, to well over 500,000 ohms when dry, have been measured, so be careful--take every safety precaution possible—it may save your life.

Figure 2-1 illustrates what a person may expect when he is subjected to increasing (current) electric shock. His first reaction occurs when the current is only 2- or 3- milliamps. At 10 milliamps, the shock is no longer a mild tingling sensation but becomes painful. As the current flow increases beyond 20 milliamps, muscular paralysis begins and the victim cannot release the contact. In the range from 50 to 100 milliamps, breathing becomes difficult—in fact it often stops. Between 100 and 200 milliamps, ventricular fibrillation (uncoordinated twitching) of the heart occurs. This is usually fatal. Above 200 milliamps severe burns will be produced, a sickening odor occurs, and the muscular reaction of the heart is so severe that it "clamps." The clamping prevents damaging ventricular fibrillation and the victim's chances of survival are good if help is immediately available.

Unfortunately it is impossible to tell whether an unconscious victim has received a fatal shock, so artificial resuscitation must be applied immediately if breathing has stopped. Do not stop efforts at resuscitation until medical authority pronounces the victim beyond help. Victims have been known to revive after 8 hours of artificial resuscitation.

If this description of the effects of shock sounds gruesome, remember that being aware of the possibility of very serious consequences will remind you to take every safety precaution available to avoid such eventualities.

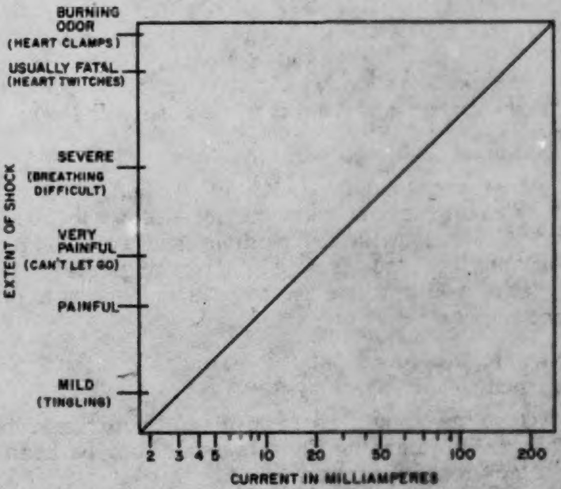
SAFE WORKING PRACTICES

When working with or around electrical equipment, don't wear loose clothing with metal buttons or metallic ornaments—they may come into contact with a live circuit and cause the wearer to flinch and come into bodily contact with exposed live parts. Remove rings, wristwatches, and metal identification bracelets and store them in a safe place (not in your pocket).

Don't examine live equipment when mentally or physically fatigued. Use rubber gloves, fuse tongs, and other safety tools and stand on a safety mat. Wear safety footwear.

Familiarity with the equipment is no excuse for taking chances. If you must work on hot equipment, don't work alone. It takes only an instant for a person to get injured and it may take minutes before the victim is discovered. Those minutes can mean the difference between life and death.

If you discover an accident victim, don't waste valuable time looking for the power switch. Use a rope, a dry length of wood, your belt, or other insulating material to pull the victim loose. The resistance of the victim's body decreases with time, and a delay in getting him loose can prove fatal.



27.314

Figure 2-1.—Electrical shock scale.

If at all possible, work on open or dead circuits. Lock and tag the power switch in the OPEN position, particularly if the switch is not in the area in which you are working. Rope off and place danger signs in hazardous areas.

Consider all circuits alive until they are proved otherwise. NEVER use your fingers to check the line; use a meter. When measuring over 300 volts, don't hold the test prods. Pull the power, clip the meter leads in place, and turn on the power. It takes longer, but it's worth it.

Don't forget to discharge large capacitors after the equipment has been turned off. Discharge them not once but twice for at least 5 seconds. A charged capacitor can pack a real wallop. Use a suitable insulated shorting or grounding bar.

Ensure that equipment is adequately grounded. Don't bridge a fuse or interlock.

Finally, do not relax caution just because protective measures have been taken. No safeguard is 100 percent effective.

LIFTING SAFELY

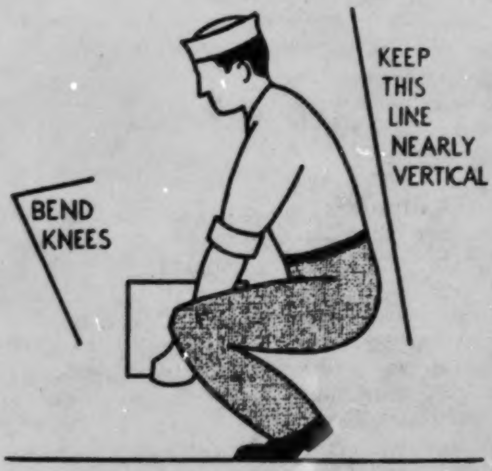
Look over the object to decide the best way to hold it. Place your feet close together and close to the object to be lifted. Get a good grip on the load. Bend your knees and keep your back straight (fig. 2-2). Keeping your body upright, lift with the leg and arm muscles, not with the back and stomach. Get a good footing and crouch when starting to lift. Take a deep breath and hold it while lifting or lowering a load.

Test the load first, lifting gradually. Avoid jerky motions and keep the load close to your body. Avoid twisting motions and don't shift positions of the feet while making the lift. Be sure you can see past the load and get help for large or heavy objects.

FIRE SAFETY

Gasoline should be kept in safety containers. Flammable cleaning fluids should not be used on electrical apparatus.

Be sure that fires are out when pots and torches are not in use.


KEEP THIS LINE NEARLY VERTICAL
BEND KNEES

90.22
Figure 2-2.—Lifting heavy material.

Closed containers should be provided for greasy rags.

Temporary wiring should not be strung over makeshift supports.

All circuits should be fused properly. You must abide by the rules for each hazardous location.

Know the proper fire extinguishers to use, particularly on electrical fires. A Class C extinguisher is preferred since it is nonconductive and can be directed against energized circuits without danger of shock.

MEMORIZE YOUR BASE FIRE TELEPHONE NUMBER. In case of fire, immediately deenergize the circuit affected. Call the Fire Department. Control the fire insofar as possible until firefighting personnel arrive.

WALKING SAFELY

It is safer to walk around trenches or other excavations than to jump over them or walk over an unsafe plank. Where hoisting or overhead work is being done, keep away from unprotected areas so you will not be struck by falling or swinging materials.

Look where you are going so you won't trip over materials or step on nails. In wet weather, be extra sure of your footing where walkways or platforms may be slippery.

HANDTOOL SAFETY

Do not use makeshift tools. Most electrical tools are specialized. For example, hot-line tools are necessary to ensure uninterrupted service. Use them correctly and do not use substitutes.

Keep all cutting tools sharp. They are safer sharp. See that jaws of wrenches are in good condition.

Tool belts should be kept in good repair for your own protection as well as for the protection of men working under you. Make sure that handles of all tools are not cracked or otherwise damaged.

LADDER SAFETY

Before climbing a ladder, make sure it is in good condition, with no cracked, split, or patched side rails, rungs, or cleats. Check the ladder to see that it is placed with the base set out one-fourth the ladder length and set firmly so it won't tip or slip. See that the top of the ladder extends at least 3 feet above the platform for a handhold to get on and off safely, and is resting firmly or tied to a support.

Use both hands for climbing. If you must carry tools, put them in a bag slung over your shoulder.

Do not use metal ladders while working around hot lines or equipment. Avoid contact with metal parts of wooden ladders.

Move the ladder when necessary. Do not try to overreach.

INSTALLATION SAFETY

Be sure of overcurrent protection since proper size wire and fuses may save a life or building. You must also be sure that temporary wiring is installed as safely as permanent wiring.

Portable tools and machines must be grounded for the protection of everybody. Be sure that flexible cords are protected as much as possible and are in good condition.

PERSONAL SAFETY

- Horseplay can result in death.

- Be sure to ground deenergized lines before performing work.

- Before energizing a line, doublecheck to make sure that everything and everyone is clear.

- Wherever possible in your work on live electrical equipment use only one hand and have a rubber glove on each hand.

- Goggles should be worn when pouring acid and when performing grinding, drilling or soldering operations.

- Know artificial respiration (discussed later).

WEAR HARD HATS

Regular protective helmets (hard hats) must provide the necessary insulation resistance so that personnel other than electrical workers will be protected from accidental head contacts with electrical circuits and equipment at comparatively low voltages (less than 2200 volts). Electrical workers requiring head protection incidental to their duties or to the working environment, particularly those engaged in transmission or distribution line installation and repair, must wear electrical worker's insulating safety helmets or all-purpose protective helmets for which the proof-test voltage is not less than 20,000 volts. The hat shown in figure 2-3 saved one man's life. Will use of a similar one save yours?

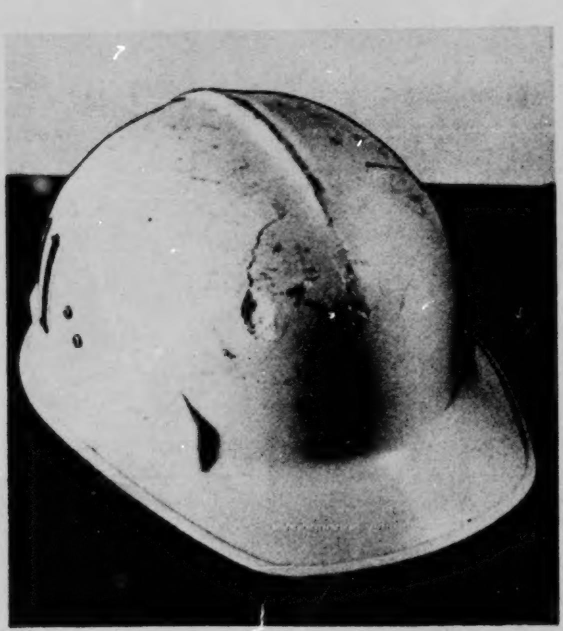
Despite the fact that most head injuries are serious, there are some workers who seem reluctant to wear hard hats. Everyone should take advantage of such valuable protection as the hard hat. Men give various reasons for refusing to wear these hats. Here are some of the common objections and reasons they do not hold true.

Objection: TOO HEAVY

Justification: Hard hats are a few ounces heavier than conventional headgear, but the extra protection is worth the extra weight. Actually, a hard hat is less than one-third the weight of an Army helmet and liner.

Objection: TOO HOT

Justification: On a hot summer day with the temperature above 100°, it may not be as comfortable as you'd like, but it is still 3° to 9° cooler than inside an ordinary hat.



26.203
Figure 2-3.—Hard hat saves man's life. Will use of a similar one save yours?

Objection: TOO COLD

Justification: Could be, but the problem is solved by wearing a winter liner. It'll keep head, neck, and ears warm without lessening the protective value.

Objection: CAUSES HEADACHES

Justification: There's no medical reason why PROPERLY ADJUSTED hard hats would bring these complaints. More than likely there's another reason such as hunger, thirst or eyestrain.

Objection: WON'T STAY ON

Justification: In a high wind, you'll need a chinstrap on your hard hat. Normally, however, that hat will stay on despite a lot of stooping and bending you may do in your work.

Objection: AMPLIFIES NOISE

Justification: Not at all. In fact, tests show that properly worn hard hats have a shielding effect on the wearer's ears. Noises are not intensified by the hat.

ELECTRICAL SAFETY REFERENCES

You must recognize that it is impossible to supply a complete list of electrical safety precautions in this manual. A number of invaluable references relating to safety are as follows:

SAFETY PRECAUTIONS FOR SHORE ACTIVITIES, NAVMAT P-5100. This reference book by Headquarters, Naval Material Command of the DEPARTMENT OF THE NAVY is an excellent guide which disseminates safety precautions known to be instrumental in preventing accidents and in maintaining a safe working environment. Chapter 15 is devoted to electrical and electronics safety. Ask your Chief Construction Electrician to let you look it over at battalion headquarters. He is sure to have it there. Knowledge of the contents of this chapter is a prerequisite for promotion to the senior levels.

NATIONAL ELECTRICAL CODE. This book, by the National Fire Protection Association, is modified and published every 3 years. It contains basic minimum provisions considered necessary for safety from electrical hazards of personnel and buildings. Requirements for electric conductors and electric equipment utilized in a variety of areas are covered. Many Navy specifications are based on these minimum requirements.

NATIONAL ELECTRICAL SAFETY CODE. This code is published by the U.S. Department of Commerce's National Bureau of Standards and should not be confused with the one described in the preceding paragraph. Handbook H-30 is another title for this book. It discusses methods of protective grounding of circuits, equipment, and lightning arresters for stations, lines, and utilization equipment. Additionally, rules for installation, operation, and maintenance of electrical supply stations and equipment, and electrical and communication lines are spelled out. Portions of this text have been superseded by National Bureau of Standards Handbook H-43.

INSTALLATION AND MAINTENANCE OF ELECTRIC SUPPLY AND COMMUNICATIONS LINES SAFETY RULES AND DISCUSSION. This publication, Handbook H-43, of the National Bureau of Standards has superseded portions of the National Electrical Safety Code related to the installation and maintenance of electric supply and communication lines. Much engineering data included in this text is useful to Construction Electricians.

SAFETY RULES FOR THE INSTALLATION AND MAINTENANCE OF ELECTRIC SUPPLY AND COMMUNICATION LINES. National Bureau of Standards Handbook 81 supersedes parts of the above listed handbooks. It is imperative that you use the latest rules and regulations in your work to minimize safety hazards.

ELECTRIC SHOCK, ITS CAUSES AND PREVENTION. This 37—page text, NAVSHIPS 250-660-42, contains vital information extremely valuable to all personnel who use electric appliances or who work around electrical equipment. It describes a variety of causes and preventions for shock. It is normally available in the battalion office or the library of the base to which you are attached. Be sure to read this manual since complete understanding of the information presented may save your life.

CLEANING

Electrical and electronic equipment must be kept clean at all times to ensure proper performance. Brushes, dusters, brooms, or other such articles which may be used within 4 feet of or on electrical equipment having exposed or current-carrying parts should not themselves contain any exposed metal parts. If a vacuum cleaner is necessary, use only with a nonmetallic hose and an adequate dust receiver.

Use only rubber or insulating hose in air lines for blowing out equipment. Use no more than 10 pounds of pressure to avoid damage to the insulation and injury to personnel. Be sure the air is free from water. Never turn compressed air on yourself or others, since it can cause serious injury.

Use sandpaper and files only upon competent advice. Emery paper should never be used on electrical equipment because of the conductive residue remaining after use.

SAFETY EQUIPMENT

Do not work on electrical apparatus with wet hands or while wearing any wet clothing. When performing work on or within 4 feet of exposed electrical equipment, do not wear any clothing with exposed zippers, buttons, or other metal fasteners, or loose or flapping clothing. Take no chances; dress appropriately. Obviously, flammable articles, such as celluloid cap visors, should not be worn. Personnel should remove rings, wristwatches, bracelets, and other similar metal items before performing work on or within 4 feet of electrical equipment with exposed current-carrying parts.

Men performing line construction and maintenance work should wear high-cut shoes with sewed soles for work on live electrical circuits above 50 volts. Thin-soled shoes and shoes with metal plates or hobnails are prohibited. Safety shoes with nonconductive soles should be worn, if available.

Keep all insulating and protective devices stored flat, and free of oils, chemicals, and other materials.

Air-test rubber gloves daily before starting work on live conductors or equipment. Testing is done by grasping the cuff of the rubber glove at opposite points and twirling (fig. 2-4). While the end is closed with one hand so the air cannot escape, squeeze the glove to force air into thumb, fingers, and palm. Hold the glove to your ear to listen for escaping air, making a thorough visual inspection for holes and thin spots, or hold the glove under water and check for air bubbles. If it is defective, tag it and turn it in for replacement.

When cutting holes in masonry material, or performing grinding or drilling operations, wear safety goggles.

Wear a hard hat—especially when working under other workers or in close quarters.

Body belts and safety straps should be inspected before each use.

Be sure that gaffs on climbers are properly sharpened. When gaffs are shorter than 1-1/4 inch, replace them.

Do not put rubber gloves or other rubber protective equipment in containers with tools.

No work should ever be done on live conductors of any voltage except in case of emergency. If the work requires that one hand be free of covering, a rubber glove should be worn on the other. Personnel intending to work on live circuits, or on equipment containing exposed current-carrying parts where the voltage is greater than 30 volts, should put on rubber gloves before coming within reach of the live parts, and should not remove the gloves until entirely clear of such equipment. Rubber gloves should not be used for any purpose except live-line electrical work.

Leather protectors should always be worn over rubber gloves and should not be used for any purpose other than with rubber gloves.

Rubber sleeves or rubber gloves should never be rolled down or worn inside out. Under no circumstances should two pairs of rubber gloves be used.

Personnel should wear rubber gloves when cutting a supposedly dead cable, or testing supposedly dead cable, or testing supposedly burned-out transformers.

TESTING RUBBER PROTECTIVE EQUIPMENT

Rubber gloves and other rubber protective equipment should be laboratory tested at intervals not to exceed the following when in regular use except as described later:

Rubber Gloves	30 days
Rubber Blankets	90 days
Rubber line hoses and hoods	180 days

In addition, before each use, they should be checked by the user for punctures, tears, or abrasions. Gloves should be air-tested. If there is evidence of any leakage or thin spots, the gloves should not be used. Electrical tests, testing equipment, and method of marking should be in accordance with current American Society for Testing and Materials (ASTM) standards. Each glove or other piece of rubber protective equipment should be marked with the last date tested. Items failing to pass the test should be replaced. Tests should be made by naval activities having the necessary equipment, by reputable electrical testing laboratories, or by local power companies which may have testing equipment and are willing to perform the tests.

All rubber protective equipment should be given a thorough visual inspection and electrical test whenever the last test was made more than 6 months prior to issue or delivery for actual use of personnel. Equipment maintained in a standby status for emergency use only may be considered to be in the same category. If it has been used more than 6 weeks, but less than 6 months, after the last test, it should again be tested before being returned to standby status or placed in regular use.

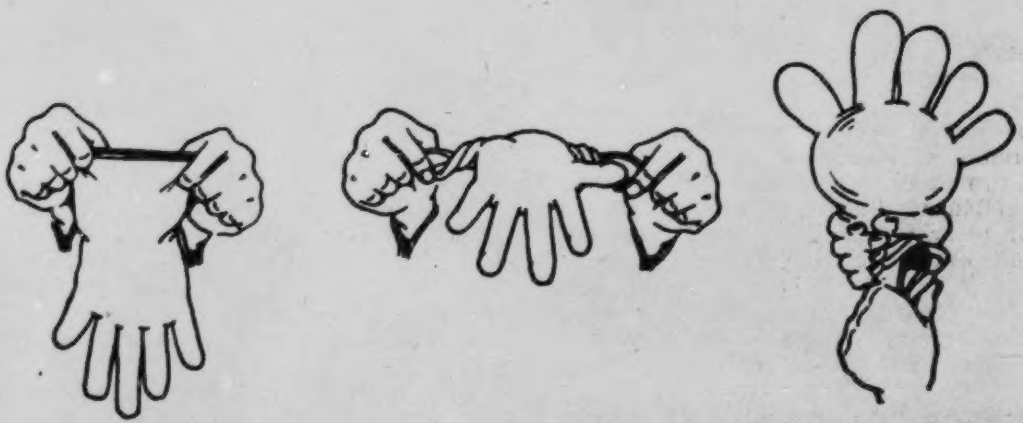


Figure 2-4.—Testing rubber gloves. 73.274

INSULATING FLOOR COVERING

On all circuits where the voltage is in excess of 30 volts, the men should be insulated from accidental grounding by use of approved insulating material on the floor at operating and working locations. The material must have the following qualities:

It should be dry, without holes, and must not contain conducting materials. The voltage rating for which it is made should be clearly marked on the material, and the proper material must be used so that optimum protection from the voltage can be supplied.

On voltage below 600 volts, dry wood may be used, or, as an alternative, at least two layers of dry canvas, sheets of phenolic material, or rubber mats. Where other than approved rubber mats are used, the marking provision of the paragraph above does not apply; however, care must be taken to ensure that substitute material is capable of providing the required insulation value.

On circuits above 600 volts, nonconducting rubber matting of an approved type should be used.

Exercise care to ensure that moisture, dust, metal chips, and so on, which may collect on insulating materials are removed at once. Small deposits of such materials can become hazardous.

PLATFORMS

Whenever it is necessary to work on electrical circuits or equipment in wet or damp locations, dry wooden (or similar nonconducting material) platforms should be provided so that there will be no possibility of contact between the wet floor and the workmen's shoes.

TOOLS

Shop machinery and handtools are frequently overlooked sources of danger to personnel. Because of their familiarity and use in everyday applications, we lose sight of their potential danger. Let's examine them.

One source of danger that often is neglected or ignored is the use of handtools which are no longer considered serviceable. Tools having plastic or wooden handles that are cracked, chipped, splintered, or broken may result in injuries to personnel from cuts, bruises or particles striking the eye. Such tools should be condemned, replaced, or if at all possible, repaired, before they cause accidents.

Another source of danger that often is neglected or ignored is the unsafe work practice of covering the metal handle of a tool with a layer of friction tape, or with a cambric sleeving, to form an improvised insulated tool. This practice does not afford an adequate insulating barrier to protect personnel from dangerous voltages; therefore, steps should be taken to ensure that this unsafe practice is not permitted.

In an emergency, when it is necessary to improvise an insulating barrier between the tool and the individual's hand, an approved method is first to apply several layers of approved rubber insulating tape (half lapped), or insulating tubing removed from scraps of electrical cable, to the metal surface areas to be covered. Then apply a layer or two of friction tape over the insulating material. In this manner, an adequate insulating barrier is provided and the possibility of accidental contact with a lethal voltage is minimized.

As a general precaution, be sure that all tools conform to Navy standards of quality and type. Use each tool only for the purpose for which it is intended. All tools in active use should be maintained in good repair and all damaged or nonworking tools should be returned to the toolkeeper. Do not leave tools on floors, platforms, ladders, or on shelves above moving machinery. Keep tools and hands free of grease, and clean tools with an approved solvent. Tools and other materials should not be thrown or dropped down to personnel working on another level. They are to be raised or lowered by means of handlines or canvas toolbags or buckets. Men should stand clear when tools and other materials are being raised or lowered.

Care must be taken when selecting pliers, side cutters, or diagonal cutters. Pliers or cutters should never be used on nuts or pipefittings. Teach your men to always hold the pliers or cutters so that the fingers are not wrapped around the handle in such a way that they can be pinched or jammed if the tool slips. When cutting short pieces, take care that parts of the work do not fly and cause injury. NEVER PUT EXTENSIONS ON TOOL HANDLES TO INCREASE LEVERAGE.

When selecting a screwdriver for electrical work, be sure that it has a nonconducting handle. The screwdriver selected should be of the proper size to fit the screw and should never be used as a substitute for a punch or a chisel. The blades of screwdrivers can be kept in proper shape with a file or a grinding wheel.

Use wrenches only if they are right for the job and only if they are in good condition. An adjustable wrench should be faced so that the movable jaw is located forward in the direction in which the handle is to be turned.

Remember to use goggles whenever the danger of flying debris exists or in any grinding operation.

Grease must be handled carefully and used only for the purpose intended. Serious injury has resulted when grease has been shot out of a grease gun in horseplay; NEVER point the gun toward another person.

Powder-actuated Tools

Powder-actuated tools should be operated, repaired, serviced, and handled only by personnel who have been trained and certified by the manufacturer, his authorized representative, or Navy Department certified instructors. In applications to concrete, approval for use of the tool should be given only after it has been ascertained that it will give satisfactory results and cause no spalling or shelling out.

As the operator of a powder-actuated tool, observe the following safety precautions:

Do not operate in an explosive or inflammable atmosphere, or in an area where nonsparking tools are required.

Whether loaded or unloaded, never point the tool at yourself or other persons; keep it pointed in a safe direction.

Before starting a day's work, check the bore of the barrel to be sure it is free of any obstruction. Failure to clean the bore may damage the barrel beyond repair. Never clear the bore by firing a powder charge. Use a piece of wire or rod.

Never carry a loaded tool away from the immediate jobsite. Be sure the tool is unloaded when not in use. Unload the tool if your work is interrupted after loading.

Be sure the tool is held perpendicular to the work surface.

Use the right guard for the job. Special guards are used where recommended.

Never attempt to drive a stud through a predrilled or prepunched hole in fixtures or material without a special guard designed for this type of operation.

In case of misfire or failure to fire, do not remove the tool from the working surface for at least 15 seconds. Open the tool and remove the powder charge BEFORE removing the guard from the work surface.

Never attempt to drive studs into very hard or brittle materials, including but not limited to cast iron, glazed tile, surface hardened steel, glass block, thin slate, live rock, face brick, or hollow tile.

When anchoring fixtures or any structural material to a concrete, steel or other subsurface suitable for stud driving, be sure there is no void or air space between the fixtures or structural material and subsurface. When working on precast concrete block, be sure to drive studs so they penetrate a wall between the cells. Lower holding power will result if studs are driven at hollow cell locations.

Never attempt to drive a stud closer to the edge of structural materials than the distance recommended by the manufacturer.

Never use the tool in material or surfaces which may be completely penetrated by the stud.

The tool operator, together with other personnel in the vicinity, should wear safety goggles or other approved safety-type face and eye protective devices and a hard hat.

CAUTION: The powder-actuated tool uses powder-loaded cartridges in its operation. Check first when handling to determine if it is loaded.

Soldering

One sizzling burn experience is usually enough to breed a healthy respect for hot objects. Many of these experiences occur during welding operations and the use of such items as soldering irons, lead pots, torches, and the fixtures used to brace, clamp, or hold them. To avoid the risk of scalding or charring your flesh, don't leave molten material or heated objects unattended. Display HOT HAZARD signs if you must leave; and return as soon as possible. Use tongs, hooks, or other protective devices to handle hot pots and pieces of stock. If there is any chance of spatter from hot flying particles, be sure to use goggles.

Soldering Irons

When using a soldering iron, bear in mind the following:

Electric soldering irons must not remain connected longer than necessary and must be kept away from flammable material.

To avoid burns, always assume that a soldering iron that is plugged in is hot.

Never rest a heated iron anywhere but on a metal surface or rack provided for this purpose. Carelessness on your part could result in fire, extensive equipment damage, and serious injuries.

Never swing an iron to remove solder because the bits of solder that come off may cause serious skin or eye burns or ignite combustible materials in the work area.

When cleaning an iron, use a cleaning cloth, but DO NOT hold the cloth in your hand. Always place the cloth on a suitable surface and wipe the iron across it to prevent burning your hand.

Hold small soldering jobs with your pliers or a suitable clamping device. Never hold the work in your hand.

It is not so obvious, but the power supply should always be disconnected from the equipment needing to be worked on, to prevent serious burns from contact with high voltages.

After completing the task requiring the use of a soldering iron, disconnect the power cord from the receptacle and, when the iron has cooled off, stow it in its assigned storage area.

SHOP MACHINERY

In your work as a Construction Electrician, you may be required to use shop machinery such as a power grinder or a drill press. In addition to the general precautions on the use of tools, there are several other precautions which should be observed when you work with machinery or assign men to operate it. The more important ones are:

Never operate mechanical or powered equipment unless you are thoroughly familiar with its controls. When in doubt, consult the appropriate instructions or ask someone who knows.

Always make sure that everyone is clear before starting or operating mechanical equipment.

Never try to clear jammed machinery without first cutting off the source of power.

When hoisting heavy machinery (or equipment) by a chain fall, always keep everyone clear, and guide the hoist with lines attached to the equipment.

Never plug in portable electric machinery without ensuring that the source is the kind of electricity (a-c or d-c) called for on the nameplate of the machine.

Drills must be straight, undamaged, and properly sharpened. Tighten the drill securely in the chuck using the key provided; never secure it with pliers or with a wrench. It is important that the drill be set straight and true in the chuck. The work should be firmly clamped and, if of metal, a center punch should be used to score the material before drilling is started.

Be sure that power cords do not come in contact with sharp objects. The cords should not be allowed to kink, nor should they be allowed to come in contact with oil, grease, hot surfaces, or chemicals. When cords are damaged, they should be replaced instead of being patched with tape.

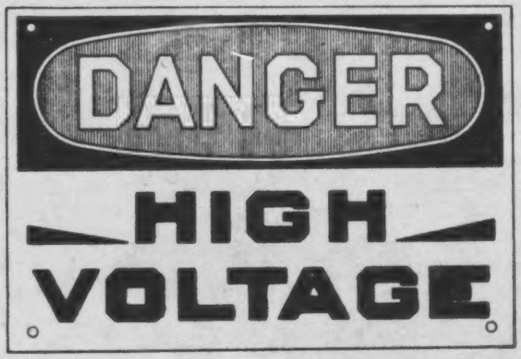
USE OF WARNING SIGNS, PLATES, AND TAGS

Warning signs and suitable guards should be provided to prevent personnel from coming into accidental contact with dangerous voltages, to warn personnel of the possible presence of explosive vapors, to warn personnel working aloft of poisonous effects of stack gases, and to warn of other dangers which may cause injuries to personnel. Equipment installation should not be considered complete until assurance has been made that appropriate warning signs have been posted in full view of operating personnel.

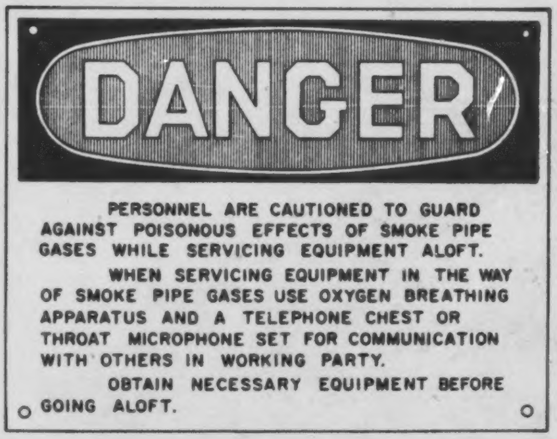
Certain types of standard electronics warning signs are available for procurement. A list of signs that are available has been distributed to all ships, commands, and shore activities. Any warning signs not listed should be ordered on a separate requesting document. Drawings of the standard warning signs most frequently used have been prepared by the Naval Ship Systems Command.

High Voltage Warning Sign, NAVSHIPS Drawing No. RE 10 B 608B (fig. 2-5) is to be displayed at all locations where danger to personnel exists, either through direct contact with high voltage or through high voltage arc over. Appropriate guards should also be installed at these locations.

Warning Sign for Personnel Working Aloft in Way of Smoke Pipe Gases, NAVSHIPS Drawing No. RE 10 AA 529A is to be displayed at the bottom and top of access ladders to electronic and electrical equipment in the way of smoke pipe gases (fig. 2-6).



40.67
Figure 2-5.—High voltage warning sign.



PERSONNEL ARE CAUTIONED TO GUARD AGAINST POISONOUS EFFECTS OF SMOKE PIPE GASES WHILE SERVICING EQUIPMENT ALOFT.

WHEN SERVICING EQUIPMENT IN THE WAY OF SMOKE PIPE GASES USE OXYGEN BREATHING APPARATUS AND A TELEPHONE CHEST OR THROAT MICROPHONE SET FOR COMMUNICATION WITH OTHERS IN WORKING PARTY.

OBTAIN NECESSARY EQUIPMENT BEFORE GOING ALOFT.

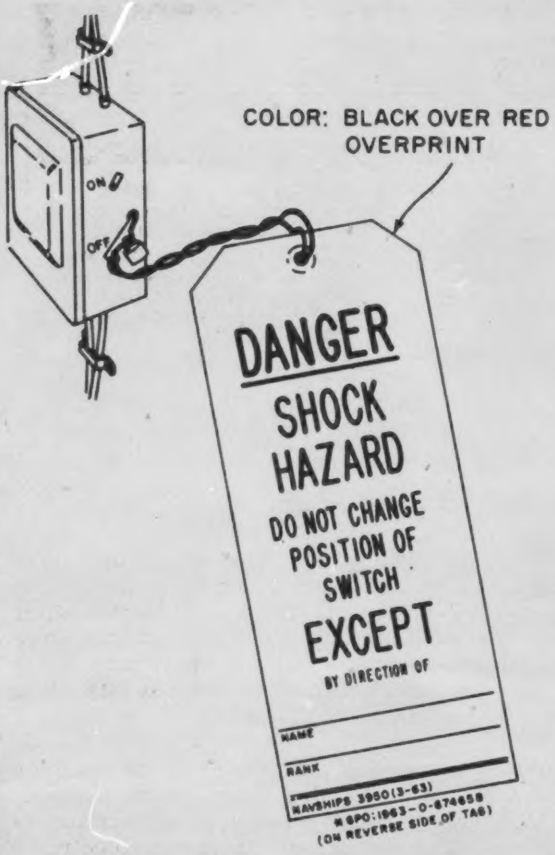
40.67
Figure 2-6.—Smoke pipe gases warning sign.

Warning signs should be temporarily displayed where explosive vapors are present in any compartment or space. No electrical or electronic equipment or auxiliary control units should be energized with areas where these signs are posted. Explosive Vapors (RE 10 A 589A) is such a sign.

Warning tags requiring open-circuit condition should be placed on all necessary power supply switches to prevent accidental application of power to units of an electrical or electronic system that are under repair or overhaul.

Warning tags, NAVSHIPS 3950(3-63), for marking open position of switches and cutout circuits (fig. 2-7), are used to indicate switches which must be left in the OFF or OPEN (safe) position during repairs. These tags are available for ship and shore personnel through normal supply channels.

Appropriate warning signs should be displayed in electrical, aviation, electronic, and special weapons shops. Danger or warning signs should be permanently posted in conspicuous places and suitable guards should be installed in appropriate areas to prevent personnel from making accidental contact with antennas, antenna leads, power supply leads or terminals, fuses, or any uncovered contacts that have sufficient voltage and current characteristics to constitute a hazard to personnel. (See figs. 2-5 and 2-6.)



40.67

Figure 2-7.—Warning tag.

GROUNDING

Metal cases, bases, frames, and other metal parts of electrical equipment, appliances, machines, and fixtures powered from supply circuits in excess of 30 volts a-c or d-c should be grounded. Where inherent grounding is not provided by the mounting arrangements, ground connections should be provided to ground the frame, enclosure, or support of permanently installed electrical equipment. Semiportable equipment which is normally used at fixed location should also be grounded. Portable electrical equipment in conductive housings should have adequate grounding.

A July 1, 1968 amendment to the specifications for electrical and electronic workbenches makes it mandatory to have a 4-foot ground lead for every 4 feet of workbench.

The grounding conductor should have a cross sectional area at least equal to, and preferably greater than, the cross sectional area of the line conductors which carry power to the equipment. The grounding conductor should make positive metal-to-metal, low resistance contact with the equipment at one end and at the other end with the metal object used as a ground, the hull of the ship in shipboard installations, and the ground rods, water pipes or installed grounding object in shore installations. The resistance between the earth and the metal object used as ground should not exceed 3 ohms.

Grounding should be checked at regular intervals after repair work has been performed, and be in accordance with the National Electric Code. Never open ground connections at ground pipe or at ground bus bars unless they first have been disconnected at the point of contact with the equipment they are intended to ground. This prevents an accident if the ground wire or bus bar should become energized. Whenever a ground wire on a pole is to be connected, make the ground pipe connection first.

DANGER FROM METAL OBJECTS

Personnel should exercise care when it is necessary to walk above open electrical equipment or exposed wires to ensure against dropping or loss of metallic objects attached to clothing.

Tools of magnetic material can be pulled into contact with dangerous circuits when these tools are used in the vicinity of electrical circuitry. Care must be taken to avoid this hazard.

INTERLOCKS AND SAFETY DEVICES

Safety devices such as interlocks, overload relays, and fuses should not be altered or disconnected except for replacement, nor should safeguard circuits be modified without specific authority.

PAINTING ELECTRICAL EQUIPMENT

Special precautions are necessary when removing paint or repainting electrical equipment. In general, the removal of paint from electrical equipment should be avoided. The use of scraping or chipping tools on such equipment is liable to injure the insulation or damage delicate parts. Furthermore, paint dust is composed of abrasive and semiconducting materials which impair the insulation. All electrical equipment, such as generators, switchboards, motors, controllers, and so on, should be covered to prevent entrance of the paint dust when paint is being scraped in the vicinity. After completion of the paint removal, the electrical equipment should be thoroughly cleaned, preferably with a vacuum cleaner, if available.

Repainting of electrical equipment should be done only when necessary to prevent incipient corrosion. The painting should then be confined to the area affected. General repainting of electrical equipment or enclosures for electrical equipment for the sole purpose of improving their appearance is not desirable. Paint should never be applied to any insulating surfaces in electrical equipment. Common sense tells you not to paint over identification plates.

PROTECTION OF NONELECTRICAL WORKERS

An insulating barrier should be provided between the work area and any live electrical parts, or the circuits should be deenergized where work is being performed within 4 feet from the exposed parts of electrical or electronic equipment by painters, carpenters, or other trades, regardless of the voltage. In all such cases, the supervisors of the nonelectrical workers should report the location of the work to the Construction Electrician in charge. The Construction Electrician should instruct the supervisors of nonelectrical workers regarding proper precautions against electrical hazards, and provide proper insulating barriers, or provide for deenergizing and locking out of circuits where possible. The supervisor of the nonelectrical workers is responsible for carrying out precautionary instructions given by the Construction Electrician in charge.

NEW INSTALLATIONS

New installations should comply with applicable rules and regulations in the National Electric Code. For example, electric light pull chains and keyed metal sockets must be of the insulated type.

ELECTRICAL SAFETY PRECAUTIONS

The safe working practices discussed so far in this chapter are applicable not only to the electrician, but to anyone working in the construction field. In addition to these general safety precautions, there are safety rules that apply specifically to electrical equipment. Here are some safety suggestions to follow when you are working on electrical tools and appliances and energized circuits.

PORTABLE EQUIPMENT

Portable electrical cables should be carefully selected and maintained. Spliced portable cables are extremely dangerous and should never be used unless an emergency warrants the great risk involved. Portable cables should be of sufficient length that they will not be subjected to longitudinal stresses or need to be pulled taut to make connections. Current-carrying capacity should be ample for all expected power demand. Portable cables should be checked frequently while in service to ascertain degree of heating. Any cable which feels more than comfortably warm to the bare hand placed outside the insulation should be checked immediately for overloading. Interconnections between lengths of portable cable should be made only on approved connection blocks or by approved fittings which should be suitably insulated and enclosed to eliminate all possible hazards from fire or shock to personnel.

PORTABLE POWER TOOLS

The hazards associated with the use of portable power tools are similar to stationary machines and include electrical shock, bruises, cuts, particles in the eye, falls, explosions, fires, and so on. Safe practice in the use of these tools will reduce or eliminate such accidents.

All portable power tools should be inspected before use to see that they are clean, well oiled, and in the proper state of repair. The switches should operate normally, and the cords should be clean and free of defects. The metal case of any electrically driven power tool should be well grounded. Sparking electric tools should never be used in places where flammable gases or liquids or exposed explosives are present. The power should always be disconnected before accessories on a portable tool are changed.

Inspect the cord and plug for proper connection. Do not use any tool that has a frayed cord or broken or damaged plug. Always connect the cord of a portable power tool into the extension cord before the extension cord is inserted into a live receptacle. Always unplug the extension cord from the receptacle before the cord of the portable power tool is unplugged from the extension cord. See that all cables are positioned so that they will not constitute tripping hazards. Wear eye protection when working where particles may strike the eyes.

After completing the task requiring the use of a portable power tool, disconnect the power cord as described above, and stow the tool in its assigned location.

PORTABLE PERSONAL EQUIPMENT

Personal radios, television sets, record players, and wire or tape recorders having metal cases or metal back or bottom are a safety hazard in many cases. In much of this type of equipment, the chassis forms a part of the circuit and the exposed metal parts are energized, thereby creating the danger of shock to personnel touching them.

The above equipment must have the safety officer's approval and must satisfy one of the following conditions to be permitted on the base:

a) The equipment has a built-in power transformer which completely isolates the primary or line side of the transformer from the secondary or equipment side. The isolation of the primary and secondary sides of the transformer must never be inferred merely from the presence of the power transformer, but must be checked by measuring the insulation resistance from each line terminal of the transformer to the chassis and exposed metal parts of the equipment. If the insulation resistance is several megohms or less, the equipment should be provided with a grounded plug and suitable cord, the grounding conductor of the cord being connected to the chassis and exposed metal parts of the equipment at one end and to the ground contact of the plug at the other end. This arrangement will ground the chassis and exposed metal parts of the equipment, but will not ground the power supply.

b) If the equipment does not have a power transformer which isolates the primary and secondary sides as described above, an isolation transformer must be installed to perform this function. A grounded plug and suitable cord should be used with the grounding conductor of the cord connected to the chassis and the power conductors of the cord connected to the primary of the isolation transformer.

The molded housing on an electric shaver is a nonconducting plastic material, and the cutting blades are isolated from any contact with the electrical components within the shaver. For this reason, 3-prong grounding plugs are not required on electric shavers. For safe use, your electric shaver should have a completely insulated housing and isolated cutting blades, and the housing and cord must be free of cracks. If there is any doubt as to whether an electric shaver complies with the above, have it checked by the electric shop. If an electric shaver falls into a washbowl of water, LET IT GO. Unplug the cord before you remove it from the water and be sure to take it to the electric shop for inspection before using it again.

Personally owned or non-Navy standard electric lights, fans, and tools could be a shock hazard because of inferior insulation, leakage currents, and flimsy structure. Periodic inspections should be made to eliminate defective appliances from the station.

Personnel are allowed to own hobby equipment if the following stipulations are met:

a) Portable, electrically operated hobby devices should be inspected and tested by the electrical crew. Equipment which passes this inspection should be tagged as safe, giving the date of inspection. This equipment should be frequently reinspected, at least once each 6 months.

b) If the hobby tool is damaged or is obviously defective, that is, if molded housings, cords, or plugs contain cracks or breaks, or if the cord insulation breaks when sharply bent, the tool must not be used until repaired and reinspected by the electrical crew.

No personal electrical equipment, such as radios, television sets, record players, wire or tape recorders, or other personal appliances as listed above, should be used without the safety officer's tag of approval. Periodic inspection should be made to enforce this vital safety regulation.

One station has been eminently successful in enforcing the above regulations by requiring the approval signature of someone in authority at the electrical shop attached to each piece of portable equipment. This signature is on a piece of colored Scotch tape. The color is then changed at required intervals. The results are obvious. Can you use this idea at your base?

OFFICE MACHINES

Sufficient attention is not always given to the dangers of low voltage electricity in offices. In general, all electrical installation in offices should be made in compliance with the rules and regulations contained in the National Electric Code. Among the more common electrical hazards found in offices are: (1) office machines, lighting fixtures, and appliances not properly grounded; (2) defective electric cords, lighting fixtures, appliances, and switches; (3) unauthorized and improperly supervised electrical connections and repairs; and (4) loose outlet plates which may result in short circuits and cause shocks through contact with them.

Before using office machines, be sure they are properly located and not in danger of falling while in use. Never clean, oil, or adjust electrical appliances when they are in operation. When cleaning appliances which are controlled by a switch on the machine, be sure the switch is turned off and the plug pulled. Protection should be provided against moving parts on addressograph, mimeograph, bookkeeping tabulating machines, and other types of power-driven machines.

Be sure that all electrical equipment is grounded. Ground wires must be connected prior to placing the machine in motion when machines are equipped with a grounded wire.

REPLACEMENT OF FUSES

Whenever practical, a circuit should be checked out before replacing a burned-out fuse. The trouble is usually indicative of a circuit fault. Since fuses are safety devices, they should be used as such. A blown fuse should be replaced by a fuse of the same rated voltage and ampere capacity. Where removable fuse links are used, only one link of the correct rating is to be used for each fuse. Insertion of metal discs or coins in the back of plug fuses or the shorting out of cartridge fuses IS STRICTLY PROHIBITED.

When it is necessary to remove a fuse, the operating switch should be opened to remove the load, and the fuse extracted with an insulated fuse puller except where, as is usually the case on switchboards, the fuses are mounted in plug type fuse holders. These fuses are removed by unscrewing the plugs.

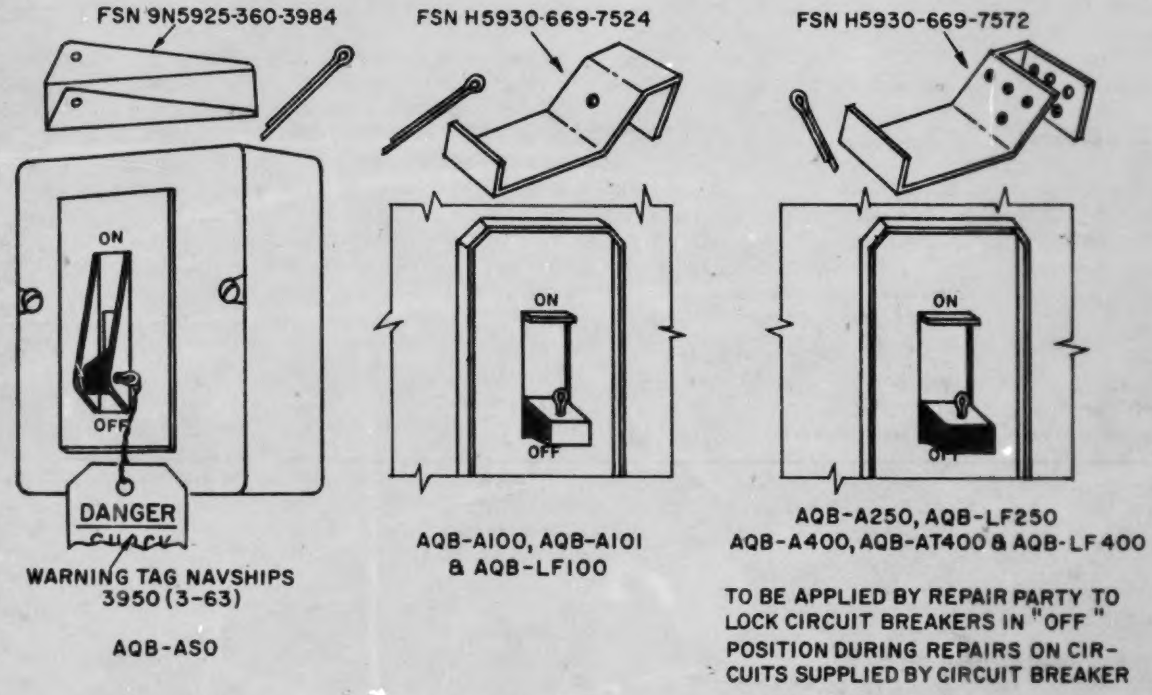
Only fuses of 10-ampere rated capacity or less should be removed from or replaced in energized circuits and only if an emergency exists.

Fuses larger than 10-ampere rated capacity should be removed or replaced only when the circuit is completely deenergized. After the replacement, the circuit should be energized only when the cover over the fuses is closed. Neglect of this precaution has led to injuries caused by explosion of a fuse when the circuit was energized.

When removing transformer fuses, wear rubber gloves with leather overgloves. This applies also to fuses which are being replaced by means of switch sticks equipped with fuse tongs or by means of regular fuse tongs, where the circuit voltage exceeds 150 volts but is less than 5,000 volts.

LOCK CIRCUIT BREAKER HANDLES AND TAG CIRCUITS

Work should not be done on any energized circuit, switchboard, controller, or other piece of electrical equipment unless the urgency of the work, together with the vital importance of the equipment concerned, dictates its necessity.



TO BE APPLIED BY REPAIR PARTY TO LOCK CIRCUIT BREAKERS IN "OFF" POSITION DURING REPAIRS ON CIRCUITS SUPPLIED BY CIRCUIT BREAKER

20.204

Figure 2-8.—Handle locking devices for circuit breakers.

Circuits to be overhauled or repaired should be deenergized by opening all switches through which the power could be supplied, and the circuit should be tested with a voltmeter or voltage tester. These switches should be tagged: "DANGER SHOCK HAZARD. Do not change position of switch except by direction of

NAME. . . . . .RATE/RANK."

Warning Tag NAVSHIPS 3950 (3-63), may be used for this purpose. In case more than one repair party is engaged in repair work on an electrical circuit, a tag for each party should be placed on the supply switches. After the work has been completed, each party should remove its own tag but no other. Loads supplied from the controller in group control centers should not be worked on until the associated circuit breaker is open. If the group controller has fuses in place of a circuit breaker, the load isolation may be accomplished by removing the fuses, provided the contactor is deenergized first.

Metal locking devices are available that can be attached to the switch handles to prevent accidental operation. These locking devices can be obtained through the Ships Parts Segment of the Navy Supply System. (See fig. 2-8.)

All breaker handles are now provided with a 3/32-inch hole permitting fastening the locking device with a standard cotter pin. On earlier breakers, it may be necessary to drill a 3/32-inch hole in the handle, using the locking device as a drilling guide. The warning tags can be attached in the eye of the cotter pin.

When checking to see whether circuits are deenergized, MAKE SURE YOU CHECK METERING AND CONTROL CIRCUITS AS WELL AS POWER CIRCUITS. In many cases metering and control circuits are connected to the supply side of a circuit breaker. A check of power circuits on the load side of a circuit breaker may show that they are dead after the circuit breaker is opened, but such a check gives no assurance whatsoever that associated metering and control circuits are dead. They may or may not be, and MUST be checked to make sure.

SWITCHBOARDS

Energized switchboards are a big source of danger. No work should be undertaken on switchboards (energized or deenergized) without first obtaining the approval of the safety officer. The commanding officer's approval must also be obtained prior to the commencement of work on an energized switchboard.

Grab rods and guardrails around switchboards and other equipment should always be in position when the equipment is energized unless emergency repairs are necessary while equipment is in service. Grab rods and guardrails should be carefully maintained to ensure that they are secure and will not accidentally be dislodged. The insulating mattings provided for covering the deck in the front and rear of switchboards should always be in place.

When maintenance work is performed on a circuit, care must be exercised to ensure that the circuit remains dead and is not energized by the closing of a remote circuit breaker. All circuit breakers or switches which could energize the circuit, if closed, should be locked open by attaching a standard locking clip to the breaker handle with a cotter pin. The locked circuit breaker should then be marked with a warning tag. The lock and tag are not to be removed until the work is complete. Even though all circuit breakers to and from a switchboard are open, it is still possible for voltage to be present in the switchboard through control circuits. Switchboard system drawings should be examined to determine if voltage could be present under such circumstances. A note of the requirement for additional protective steps should be added to the standard procedures for maintaining or troubleshooting in such switchboards.

Where removable covers (plates or grilles) are provided on switchgear units, great care should be used in removal when equipment is energized. For example, unless care is exercised, a large grille cover on the rear of a switchboard section may tip in at the top or bottom after removal of some of the fastenings or while it is being lifted off. This may result in contact with a live part, thereby causing a short circuit, an arc, or injury to personnel.

Great care should be exercised to avoid contact with any live parts of the switchboards. Many deaths have been caused by personnel in the rear of the switchboards being thrown against live bus bars or terminals. Rear-service switchboards are required to have an expanded metal enclosure with a door, enclosing all means of access to the rear of the switchboard. Battens must be kept in place. The door should be kept locked. In the case of front-service switchboards, hinged panels should not be opened except in an emergency and not until the entire switchboard is completely deenergized.

All structural parts, bases, frames, and all other metal parts of a switchboard which are not intended to operate above ground potential should be grounded. Care must be taken to remove all paint and dirt from around the mounting bolts to ensure a positive electric grounding connection. Where such inherent grounding is not provided, as in the case of some switchboards in which shock mounts are used, ground connections must be provided. If structural and other metal parts are not grounded, a breakdown of insulation may raise them to full line voltage and create a hazard.

BATTERY CHARGING

When engaged in electrolyte handling, mixing, or filling operations, personnel should wear face shields and chemically resistant gloves, footwear and aprons. To protect the eyes from burning caused by splashing, goggles should be worn. Deluge showers and eyewash fountains should be provided in the immediate vicinity of all battery maintenance and electrolyte handling operations. If an emergency occurs, quick use of these facilities may save a man's vision.

Water should NEVER be poured directly into battery acid. The acid must always be poured SLOWLY into the water to prevent excessive heating, and CAUTIOUSLY to prevent splashing. The strong acid will cause painful burns. The solution should be stirred continuously to prevent the heavier acid from flowing to the bottom of the tank without mixing.

Be sure to open the switch prior to removing connections from the batteries while they are being charged, since an inadvertent spark may cause an explosion of any escaping hydrogen. For the same reason, never smoke in this area, and be sure to provide adequate ventilation.

ENERGIZED CIRCUITS OR EQUIPMENT

Repairs are not to be made on energized circuits except in an emergency. The commanding officer or his authorized representative determines whether an emergency exists. When military considerations require that electrical repair or maintenance work be performed, but prohibit deenergizing the circuits involved, extreme measures of precaution must be used. The work should be accomplished only by adequately supervised personnel fully cognizant of the dangers involved. Every care should be taken to insulate the person performing the work from ground and to use all practical safety measures. The following precautions should be taken when applicable:

Provide ample illumination.

The person doing the work should not wear wristwatch, rings, watch chain, metal articles, or loose clothing which might make accidental contact with live parts, or which might accidentally catch and throw some part of his body into contact with live parts. Clothing and shoes should be as dry as possible.

Insulate the worker from ground by means of insulating material covering any adjacent grounded metal with which he might come in contact. Suitable insulating materials are dry wood, rubber mats, dry canvas, dry phenolic material, or even heavy dry paper in several thicknesses. Be sure that any such insulating material is dry, has no holes in it, and no conducting materials embedded in it. Cover sufficient areas so that adequate latitude is permitted for movement by the worker in doing the work.

Insofar as practical, provide insulating barriers between the work and any live metal parts immediately adjacent to the work to be done.

Use only one hand in accomplishing the work, if practical.

A rubber glove should be used on the hand not used for handling tools. If the work being done permits, rubber gloves should be worn on both hands.

Have men stationed by circuit breakers or switches, and telephone manned if necessary, so that the circuit or switchboard can be deenergized immediately in case of emergency.

A man qualified in mouth-to-mouth resuscitation and cardiac massage for electric shock should be immediately available while the work is being done.

Make sure that the connections of removable test leads on portable meters are tight. The free end of an energized test lead which comes adrift from its meter during a check of live circuits is a shock and fire hazard.

Checking the Circuit

When a circuit below 600 volts is to be checked, the voltmeter or voltage tester should first be tested on a circuit known to be operating in order to determine if the testing device is in good condition. When voltages of 600 volts or more are to be measured, the following precautions are to be observed:

(1) Deenergize the equipment to be tested.

(2) High voltage capacitors and the terminals to which the test equipment is to be connected should be discharged at least twice, with a minimum 15-second interval, by the use of a suitable insulated shorting or grounding bar.

(3) Attach a temporary, but secure, ground to the circuit.

(4) Ascertain that the test equipment controls are set correctly for testing of the high voltages.

(5) Connect to the desired test points the test leads capable of safely carrying the high voltages.

(6) Remove the temporary ground from the circuit.

(7) Withdraw from the equipment under test, making sure that you are free from the leads and in a proper position for taking meter readings correctly.

Taking the Measurements

(1) Do not use flexible leads or probes that are attached temporarily.

(2) Assign the responsibility of energizing the equipment to an assistant standing by the switch.

(3) Do not touch the test instruments while the power is on.

(4) After taking the reading, deenergize the equipment.

(5) Before removing the test leads, discharge high voltage capacitors and the terminals to which the test equipment is connected at least twice, with a minimum 15-second interval, by the use of a suitable insulated shorting or grounding bar.

(6) Attach temporary ground to the terminals to which the test instrument is connected.

(7) Remove the test leads.

(8) Remove the temporary ground.

(9) Repeat the above precautions for each measurement at applicable.

Low Voltage Work, 0 to 600 Volts

Live conductors and equipment operating at 600 volts or less may be worked upon if the following requirements are met:

(1) Adjacent live or grounded conductors and equipment should be covered with insulating material or approved rubber protective equipment.

(2) Two men should work together, particularly when work is done on energized parts carrying more than 150 volts, in wet weather, or at night. When working on energized lines, a man should not change his position on a pole without first informing others working nearby.

(3) Bare or exposed places on one conductor must be taped or covered before another conductor is exposed.

Intermediate Voltage Work, 600 to 5,000 Volts

(1) Testing Voltage Meters. All conductors and equipment must be considered as carrying current and as being alive until it has been determined beyond doubt that they are dead. When positive proof as to whether a conductor or a piece of equipment is energized cannot be established by a visual check, an approved voltage detector should be used. Before being used, the detector must be checked on a conductor that is known to be alive and a positive indication noted. This check on a known live conductor must be repeated after the test on a dead conductor has been made. When it is not possible to recheck the voltage detector on a live conductor, two voltage detectors should be used, one as a check against the other.

(2) Insulating Equipment. When work is to be done on or within reach of conductors or equipment operating between 600 and 5,000 volts, energized and grounded conductors or equipment within reach must be isolated with suitable barriers or covered with rubber hose line, insulator hoods, line protectors (pigs), or blankets. If it becomes necessary for the workman to change his working position, he must cover or barricade any energized or grounded conductors or equipment that will be within reach in the new position.

High Voltage Work, 5,000 Volts and Over

Lines and equipment operating at 5,000 volts or over must be deenergized and grounded before work is started, except in emergency repairs on overhead lines, which may be worked on alive with approved hot-line tools.

Body Clearance for High Voltage Work

A minimum body clearance from energized lines and equipment should be maintained by men working on or around electrical equipment of high voltage, as shown below:

Operating Voltage (Kilovolts)	Minimum Distance (Feet)
5 to 7.5	1
7.5 to 12	2
12 to 33	3

Remember: Never hold a line clear of a lineman on the pole. Secure it by live-line tools and lock it in a clamp.

Additional information relative to safety may be obtained from the Department of the Navy Safety Precautions for Shore Activities, NAVMAT

P-5100. Become familiar with its contents. This knowledge may save your life or the lives of some of your men.

Live-Line Barehand Work

The live-line barehand technique utilizing the insulated aerial servicing platform is prohibited unless specific approval is granted by the Naval Facilities Engineering Command.

Use and Care of Hot-Line Tools

The following precautions must be taken when hot-line tools are used:

(1) Work with hot-line tools should not be performed when rain or snow is imminent or falling, or when heavy fog, dew, or any form of excessive moisture is present.

(2) When working on lines energized at more than 5,000 volts, use approved hot-line tools WITHOUT rubber gloves. (Rubber gloves prevent detection of brush discharges.) Handle series street lighting circuits supported on arms with other lines energized at more than 5,000 volts, the same as the power supply conductors.

(3) No more than one conductor may be worked on at a time with hot-line tools.

(4) Hot-line tools must be kept dry and free from dirt. Tools which have been subjected to damp weather must be thoroughly dried and tested before being used again. They must never be placed on the ground.

(5) Hot-line tools being transported on line trucks should be stored so as to prevent damage to them. Waterproof canvas bags may be used for this purpose. A compartment equipped with padded hooks or binds may be built into the truck for this purpose.

Periodic treatment of hot-line tools in a drying cabinet for 48 hours to 1 week per month at 90 to 100 degrees Fahrenheit is recommended under average conditions. Hot-line sticks must be tested with 75,000 volts per foot for 5 minutes. If they break down, they must be returned to the drying room.

WORLD'S BEST PROTECTIVE DEVICE

In setting forth these rules and regulations for safe practices, it is fully recognized that all possible hazardous conditions cannot be foreseen and covered by adequate precautionary measures. Mental alertness and effective procedures in handling equipment and performing work are required at all times by all men so that hazards may be detected and overcome before they lead to personnel injury, or damage to equipment.

Remember

THE WORLD'S BEST
PROTECTIVE DEVICE
IS A CAREFUL INDIVIDUAL

FIGHTING FIRES

It is extremely important that all personnel know and understand all there is to know about fire prevention and firefighting. Part of the knowledge is to know the type and location of all firefighting equipment and apparatus in the immediate working and living spaces, and throughout the area. It is too late to get this knowledge after a fire has started; the time is now. Remember—If there is a special phone number on your base to call in case of fire, require all the men to memorize it. The time lost looking for this emergency number may put the fire beyond control.

RULES TO FOLLOW

In case of an electrical fire proceed as follows:

1. Deenergize the circuit or equipment affected and shift the load to standby circuits or equipment. In case no standby circuit or equipment is available, deenergize the circuit or equipment affected by the fire, except in extreme emergency when the need for uninterrupted power outweighs the risk incurred by leaving it energized.

2. Report the fire.

3. Secure ventilation by closing air vents or windows.

4. Attack the fire with portable CO_2 extinguishers (or a CO_2 hose reel system, if available) as follows:

a. Remove the locking pin from the release valve.

b. Grasp the horn handle by the insulated (thermal) grip; the grip is insulated against possible hand frostbite.

c. Squeeze the release lever (or turn the wheel) to open the valve and thus release the carbon dioxide; at the same time, direct the discharge flow of the carbon dioxide toward the base of the fire.

d. Aim and move the horn of the extinguisher slowly from side to side.

e. Do not stop the discharge from the extinguisher too soon. When the fire has been extinguished, coat the critical surface areas involved with carbon dioxide "snow" in order to cool the substances (fuels) involved and prevent a rekindling of the fire.

Care must be taken to avoid high concentrations of carbon dioxide in confined spaces, as there is danger of suffocation to personnel unless special apparatus is available. In electrical fires, remember that quick action is most needed for deenergizing the circuit. When this has been done, stop, look, and think, and then act fast to extinguish the fire before it spreads.

Carbon dioxide is the preferred fire extinguisher for use on electrical fires. It is a noncorrosive gas which does not damage cables or equipment. It is nonconducting, and the stream of carbon dioxide from an extinguisher can be directed against energized circuits without danger of shock.

Extreme care must be used if freshwater or saltwater or foam is directed at an energized circuit, since all of these can conduct current and shock firefighters. In addition, equipment damaged by saltwater or foam is more difficult to recondition than if carbon dioxide had been used. Consequently, while water or foam may have to be used to prevent a disastrous fire, it is decidedly advantageous and preferable to use carbon dioxide alone.

In cases of cable fires, in which the inner layers of insulation or insulation covered by armor are burning, the only positive method of preventing the fire from running the length of the cable is to cut the cable. Use an ax with a wooden handle, taking care to protect your eyes from any flash when the wires are severed, and separate the two ends.

Don't forget to request the replacement or recharge of fire extinguishers immediately after they have been discharged. Never turn on current in a building in which a fire has occurred, if electric wiring has been affected. A careful inspection should be made, because parts damaged by heat, water, or foam may become short circuited and restart the fire.

PREVENTING FIRES

General cleanliness of the work area and of electrical apparatus is essential for the prevention of fires. Oil, grease, and carbon dust can be ignited by electrical arcing. Therefore, electrical equipment should be kept absolutely clean and free of all such deposits.

Wiping rags and other flammable waste material must always be placed in tightly closed metal containers, which must be emptied at the end of the day's work.

Containers holding paints, varnishes, cleaners, or any volatile solvents should be kept tightly closed when not in actual use. They must be stored in a separate building or in a fire-resisting room which is well-ventilated and where they will not be exposed to excessive heat or to the direct rays of the sun.

Alcohol should never be used for cleaning electrical equipment since it not only constitutes a fire hazard, but it also results in damage to many kinds of insulation. When cleaning electrical equipment or parts, always use an approved cleaning agent such as FSN W 6850-274-5421. It is a dry cleaning solvent, Type II, covered by the latest issue of Specification D-680.

SAFETY EDUCATION

Many supervisors feel that it is only necessary to provide safeguards, after which safety will take care of itself. Provision of safeguards is a move in the right direction, but it alone will not get good results. To maintain a good safety record, you, as the supervisor, need to employ a combination of safety devices and safety training. If each man has had sound safety training, he will be able to guard against hazards for which safety devices are impracticable. You must, however, train every man in the use of safeguards, explaining why, as well as how, they should be used. How many times have you seen a man shut off the power to a motor-driven machine and then walk away from it before it has stopped turning? This man knew how, but not why. By providing the necessary training, the alert supervisor makes sure his men are not careless with safeguards.

Standup safety meetings should be held in the shop once every week. The meetings should be held at or near the work area. Instead of a routine safety lecture, it is better to hold a group discussion on specific accidents that are to be guarded against or that have happened in the unit. The men should be encouraged to express their ideas. Your group should reach a conclusion as to how specific accidents can be prevented.

Another type of safety meeting is one in which the supervisor presents a safety problem that has developed because of new work or new equipment. Again, the men should be invited to express their ideas.

In a third type of safety meeting, actual demonstrations and practice by the group are carried out. You demonstrate how to lift, for example, and then have the men practice lifting.

If the subject of your safety meeting is the safe use of a portable grinder, bring a portable grinder to the meeting and show how to use it—do not just talk about how to use it. Again, let the men practice after they have been shown how.

Make these meetings interesting; it takes a lot of ingenuity to keep them from becoming dull. Consider having the men themselves rotate as leaders of the safety meetings—an excellent device to maintain interest. Hundreds of good motion pictures and other visual aids are available on safety subjects. Use them! But select subject mater that is timely and fitting. Never complain or scold at these meetings. Also, make sure to set a time limit for each meeting, and avoid exceeding it.

ACCIDENT REPORTING

When an accident occurs in your shop, office, or within your crew, you must fill out an OPNAV Form 5100/1, Accidental Injury/Death Report (figs. 2-9 through 2-12). This form provides a method of recording the essential facts concerning an accident, from which data for use in accident prevention can be compiled. Item 27—"Corrective action taken/recommended"—is the most important part of this report. Your response to this item provides a clue to your attitude toward safety. Too many supervisors respond with, "The man was warned to be more careful." Such a response is useless since it does not tie in with the rest of the report. If an unsafe working condition is the cause of the accident, you cannot correct it by warning the man to be more careful. Study the report; analyze it; then take corrective action. When properly used, this report is one of your best accident prevention tools. In many cases, the difference between a minor accident and a major one is a matter of luck. Do not ignore accidents that result in small cuts and bruises; investigate the reasons for them and correct the causes. If you do this, you will have a safe and efficient shop or office.

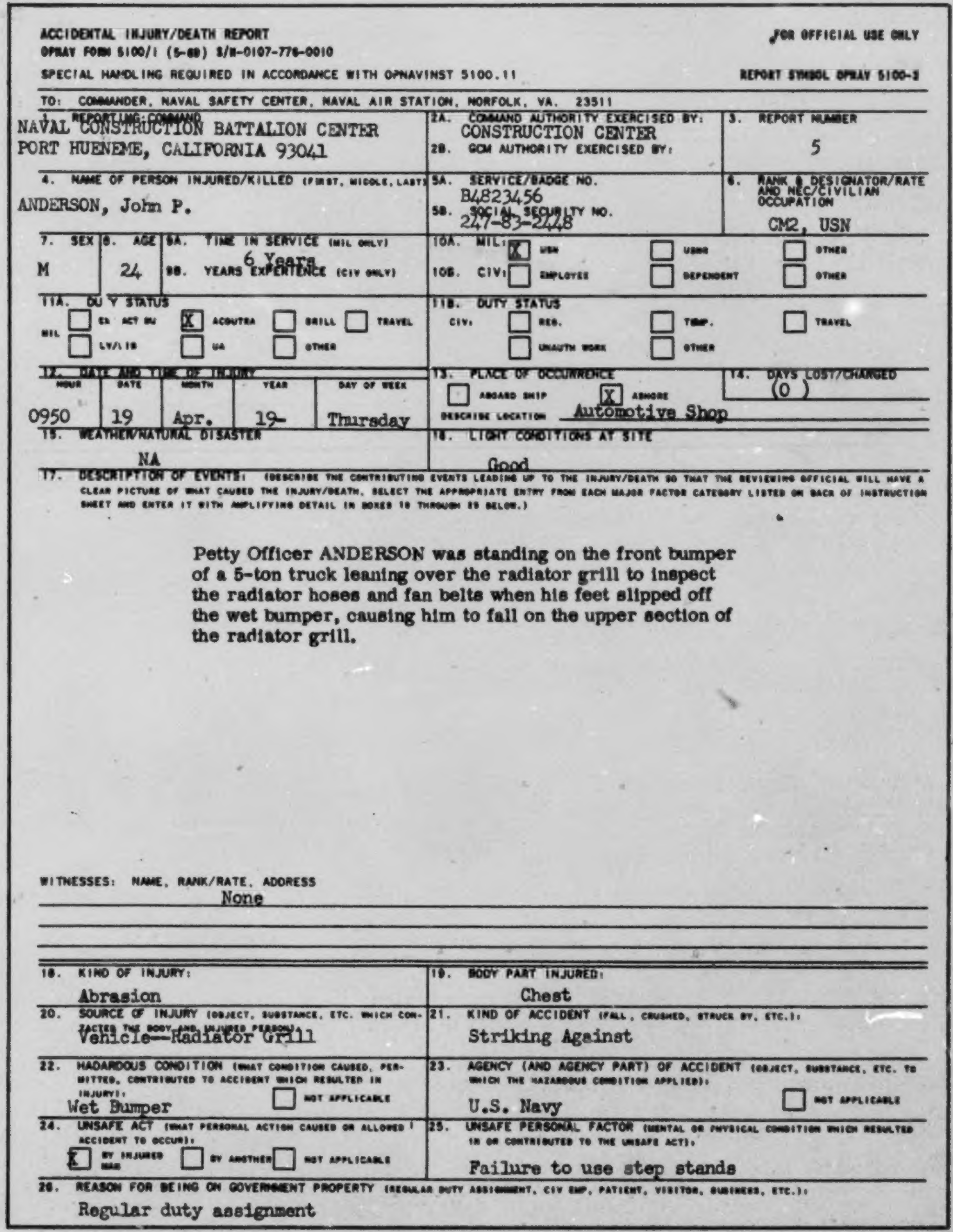
ACCIDENT INVESTIGATION

To fill out OPNAV Form 5100/1 properly, as shown in figures 2-9 and 2-10, you must conduct an accident investigation to get answers to questions such as those in the six categories below.

1. UNSAFE CONDITIONS. Was the equipment improperly guarded? Was the equipment or material rough, slippery, sharp-edged, decayed, worn, or cracked? Was there a hazardous arrangement, such as congested work space, lack of proper lifting equipment, or unsafe planning? Was there proper illumination or ventilation? Was the man dressed properly for the job? Was the man provided with proper respirator, goggles, gloves, etc?

2. TYPE OF ACCIDENT. Was the man struck by an object? Did the man fall at the same level or to a different level? Was he caught in or between objects? Did he slip (not fall) or overexert himself?

3. UNSAFE ACT. Was the man operating a machine without proper authorization? Was he



ACCIDENTAL INJURY/DEATH REPORT
OPNAV FORM 5100/1 (5-69) S/N-0107-776-0010
SPECIAL HANDLING REQUIRED IN ACCORDANCE WITH OPNAVINST 5100.11

FOR OFFICIAL USE ONLY
REPORT SYMBOL OPNAV 5100-3

TO: COMMANDER, NAVAL SAFETY CENTER, NAVAL AIR STATION, NORFOLK, VA. 23511

1. REPORTING COMMAND
NAVAL CONSTRUCTION BATTALION CENTER
PORT HUENEME, CALIFORNIA 93041

2A. COMMAND AUTHORITY EXERCISED BY: CONSTRUCTION CENTER
2B. GCM AUTHORITY EXERCISED BY:

3. REPORT NUMBER: 5

4. NAME OF PERSON INJURED/KILLED (FIRST, MIDDLE, LAST): ANDERSON, John P.

5A. SERVICE/BADGE NO.: B4823456
5B. SOCIAL SECURITY NO.: 247-83-2448

6. RANK & DESIGNATOR/RATE AND NEC/CIVILIAN OCCUPATION: CM2, USN

7. SEX: M
8. AGE: 24
9A. TIME IN SERVICE (MIL ONLY): 6 Years
9B. YEARS EXPERIENCE (CIV ONLY)

10A. MIL: ☒ USN ☐ USNR ☐ OTHER
10B. CIV: ☐ EMPLOYEE ☐ DEPENDENT ☐ OTHER

11A. DUTY STATUS
MIL: ☐ EX ACT DU ☒ ACDUTRA ☐ DRILL ☐ TRAVEL
☐ LV/LIB ☐ UA ☐ OTHER

11B. DUTY STATUS
CIV: ☐ REG. ☐ TEMP. ☐ TRAVEL
☐ UNAUTH WORK ☐ OTHER

12. DATE AND TIME OF INJURY

HOUR	DATE	MONTH	YEAR	DAY OF WEEK
0950	19	Apr.	19-	Thursday

13. PLACE OF OCCURRENCE
☐ ABOARD SHIP ☒ ASHORE
DESCRIBE LOCATION: Automotive Shop

14. DAYS LOST/CHARGED: (0)

15. WEATHER/NATURAL DISASTER: NA

16. LIGHT CONDITIONS AT SITE: Good

17. DESCRIPTION OF EVENTS: (DESCRIBE THE CONTRIBUTING EVENTS LEADING UP TO THE INJURY/DEATH SO THAT THE REVIEWING OFFICIAL WILL HAVE A CLEAR PICTURE OF WHAT CAUSED THE INJURY/DEATH. SELECT THE APPROPRIATE ENTRY FROM EACH MAJOR FACTOR CATEGORY LISTED ON BACK OF INSTRUCTION SHEET AND ENTER IT WITH AMPLIFYING DETAIL IN BOXES 18 THROUGH 25 BELOW.)

Petty Officer ANDERSON was standing on the front bumper of a 5-ton truck leaning over the radiator grill to inspect the radiator hoses and fan belts when his feet slipped off the wet bumper, causing him to fall on the upper section of the radiator grill.

WITNESSES: NAME, RANK/RATE, ADDRESS
None

18. KIND OF INJURY: Abrasion

19. BODY PART INJURED: Chest

20. SOURCE OF INJURY (OBJECT, SUBSTANCE, ETC. WHICH CONTACTED THE BODY AND INJURED PERSON): Vehicle—Radiator Grill

21. KIND OF ACCIDENT (FALL, CRUSHED, STRUCK BY, ETC.): Striking Against

22. HAZARDOUS CONDITION (WHAT CONDITION CAUSED, PERMITTED, CONTRIBUTED TO ACCIDENT WHICH RESULTED IN INJURY): Wet Bumper ☐ NOT APPLICABLE

23. AGENCY (AND AGENCY PART) OF ACCIDENT (OBJECT, SUBSTANCE, ETC. TO WHICH THE HAZARDOUS CONDITION APPLIED): U.S. Navy ☐ NOT APPLICABLE

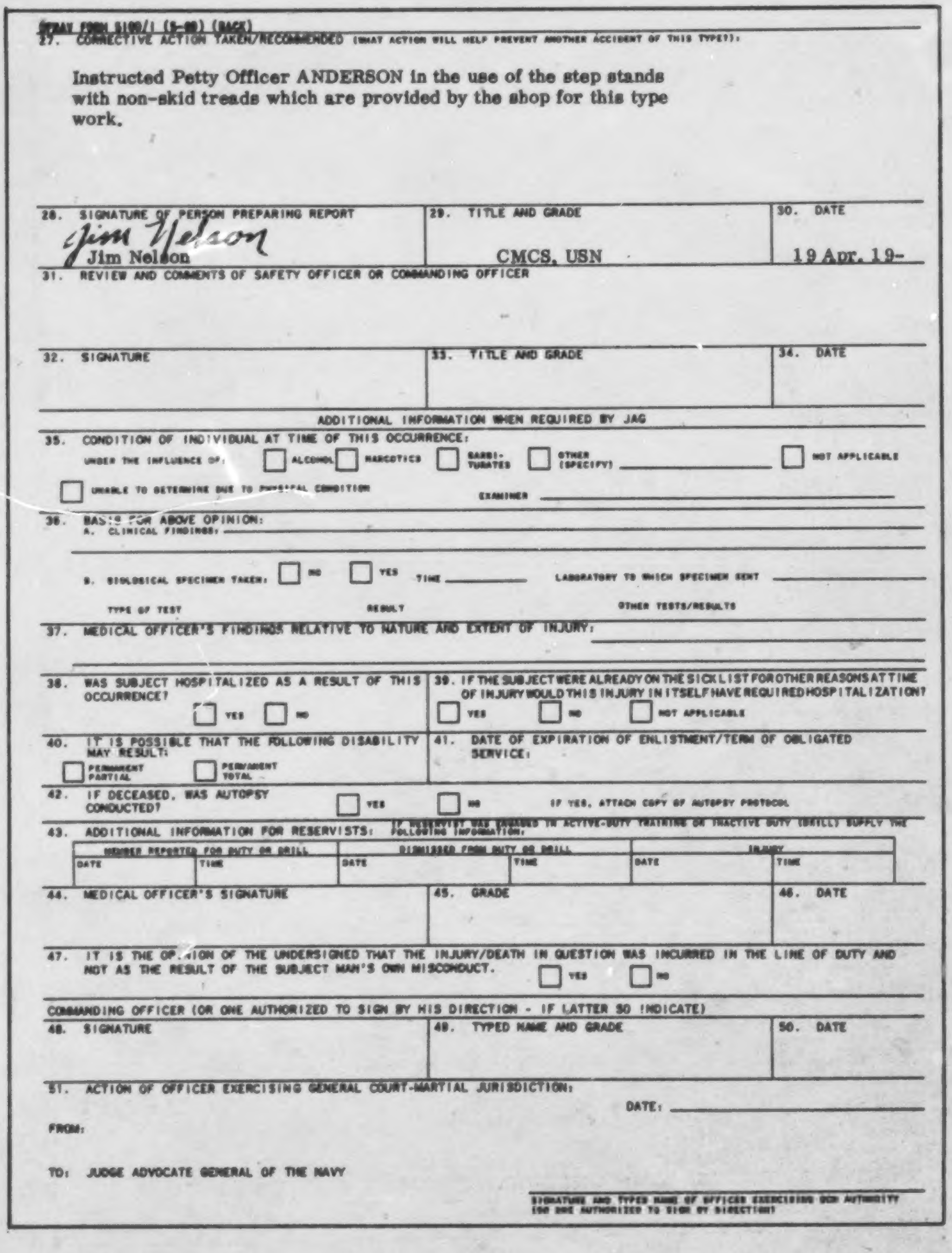
24. UNSAFE ACT (WHAT PERSONAL ACTION CAUSED OR ALLOWED ACCIDENT TO OCCUR): ☒ BY INJURED MAN ☐ BY ANOTHER ☐ NOT APPLICABLE

25. UNSAFE PERSONAL FACTOR (MENTAL OR PHYSICAL CONDITION WHICH RESULTED IN OR CONTRIBUTED TO THE UNSAFE ACT): Failure to use step stands

26. REASON FOR BEING ON GOVERNMENT PROPERTY (REGULAR DUTY ASSIGNMENT, CIV EMP, PATIENT, VISITOR, BUSINESS, ETC.): Regular duty assignment

29.52.1

Figure 2-9.—Accidental Injury/Death Report, OPNAV Form 5100/1 (front).



OPNAV FORM 5100/1 (5-80) (BACK)

27. CORRECTIVE ACTION TAKEN/RECOMMENDED (WHAT ACTION WILL HELP PREVENT ANOTHER ACCIDENT OF THIS TYPE?):

Instructed Petty Officer ANDERSON in the use of the step stands with non-skid treads which are provided by the shop for this type work.

28. SIGNATURE OF PERSON PREPARING REPORT Jim Nelson Jim Nelson	29. TITLE AND GRADE CMCS, USN	30. DATE 19 Apr. 19-

31. REVIEW AND COMMENTS OF SAFETY OFFICER OR COMMANDING OFFICER

32. SIGNATURE	33. TITLE AND GRADE	34. DATE

ADDITIONAL INFORMATION WHEN REQUIRED BY JAG

35. CONDITION OF INDIVIDUAL AT TIME OF THIS OCCURRENCE:
UNDER THE INFLUENCE OF: ☐ ALCOHOL ☐ NARCOTICS ☐ BARBITURATES ☐ OTHER (SPECIFY) ______ ☐ NOT APPLICABLE
☐ UNABLE TO DETERMINE DUE TO PHYSICAL CONDITION   EXAMINER ______

36. BASIS FOR ABOVE OPINION:
A. CLINICAL FINDINGS: ______
B. BIOLOGICAL SPECIMEN TAKEN: ☐ NO ☐ YES   TIME ______   LABORATORY TO WHICH SPECIMEN SENT ______
TYPE OF TEST   RESULT   OTHER TESTS/RESULTS

37. MEDICAL OFFICER'S FINDINGS RELATIVE TO NATURE AND EXTENT OF INJURY: ______

38. WAS SUBJECT HOSPITALIZED AS A RESULT OF THIS OCCURRENCE? ☐ YES ☐ NO	39. IF THE SUBJECT WERE ALREADY ON THE SICK LIST FOR OTHER REASONS AT TIME OF INJURY WOULD THIS INJURY IN ITSELF HAVE REQUIRED HOSPITALIZATION? ☐ YES ☐ NO ☐ NOT APPLICABLE
40. IT IS POSSIBLE THAT THE FOLLOWING DISABILITY MAY RESULT: ☐ PERMANENT PARTIAL ☐ PERMANENT TOTAL	41. DATE OF EXPIRATION OF ENLISTMENT/TERM OF OBLIGATED SERVICE:

42. IF DECEASED, WAS AUTOPSY CONDUCTED? ☐ YES ☐ NO   IF YES, ATTACH COPY OF AUTOPSY PROTOCOL

43. ADDITIONAL INFORMATION FOR RESERVISTS: IF RESERVIST WAS ENGAGED IN ACTIVE-DUTY TRAINING OR INACTIVE DUTY (DRILL) SUPPLY THE FOLLOWING INFORMATION:

MEMBER REPORTED FOR DUTY OR DRILL		DISMISSED FROM DUTY OR DRILL		INJURY	
DATE	TIME	DATE	TIME	DATE	TIME

44. MEDICAL OFFICER'S SIGNATURE	45. GRADE	46. DATE

47. IT IS THE OPINION OF THE UNDERSIGNED THAT THE INJURY/DEATH IN QUESTION WAS INCURRED IN THE LINE OF DUTY AND NOT AS THE RESULT OF THE SUBJECT MAN'S OWN MISCONDUCT. ☐ YES ☐ NO

COMMANDING OFFICER (OR ONE AUTHORIZED TO SIGN BY HIS DIRECTION - IF LATTER SO INDICATE)

48. SIGNATURE	49. TYPED NAME AND GRADE	50. DATE

51. ACTION OF OFFICER EXERCISING GENERAL COURT-MARTIAL JURISDICTION:

DATE: ______

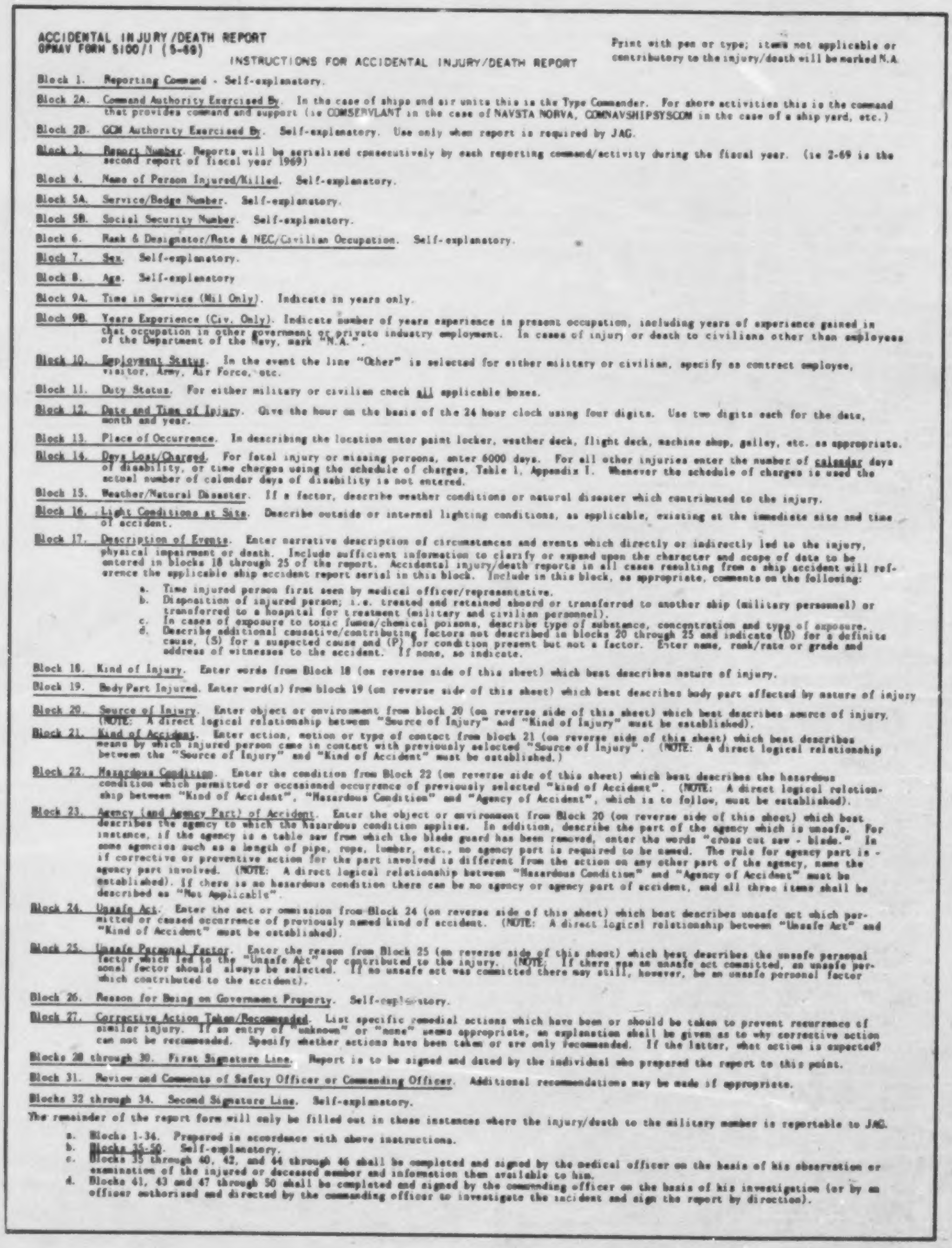
FROM:

TO: JUDGE ADVOCATE GENERAL OF THE NAVY

SIGNATURE AND TYPED NAME OF OFFICER EXERCISING GCM AUTHORITY (OR ONE AUTHORIZED TO SIGN BY DIRECTION)

29.52.2

Figure 2-10.—Accidental Injury/Death Report, OPNAV Form 5100/1 (back).



ACCIDENTAL INJURY/DEATH REPORT
OPNAV FORM 5100/1 (5-69)

Print with pen or type; items not applicable or contributory to the injury/death will be marked N.A.

INSTRUCTIONS FOR ACCIDENTAL INJURY/DEATH REPORT

Block 1. Reporting Command - Self-explanatory.

Block 2A. Command Authority Exercised By. In the case of ships and air units this is the Type Commander. For shore activities this is the command that provides command and support (ie COMSERVLANT in the case of NAVSTA NORVA, COMNAVSHIPSYSCOM in the case of a ship yard, etc.)

Block 2B. GCM Authority Exercised By. Self-explanatory. Use only when report is required by JAG.

Block 3. Report Number. Reports will be serialized consecutively by each reporting command/activity during the fiscal year. (ie 2-69 is the second report of fiscal year 1969)

Block 4. Name of Person Injured/Killed. Self-explanatory.

Block 5A. Service/Badge Number. Self-explanatory.

Block 5B. Social Security Number. Self-explanatory.

Block 6. Rank & Designator/Rate & NEC/Civilian Occupation. Self-explanatory.

Block 7. Sex. Self-explanatory.

Block 8. Age. Self-explanatory

Block 9A. Time in Service (Mil Only). Indicate in years only.

Block 9B. Years Experience (Civ. Only). Indicate number of years experience in present occupation, including years of experience gained in that occupation in other government or private industry employment. In cases of injury or death to civilians other than employees of the Department of the Navy, mark "N.A.".

Block 10. Employment Status. In the event the line "Other" is selected for either military or civilian, specify as contract employee, visitor, Army, Air Force, etc.

Block 11. Duty Status. For either military or civilian check all applicable boxes.

Block 12. Date and Time of Injury. Give the hour on the basis of the 24 hour clock using four digits. Use two digits each for the date, month and year.

Block 13. Place of Occurrence. In describing the location enter paint locker, weather deck, flight deck, machine shop, galley, etc. as appropriate.

Block 14. Days Lost/Charged. For fatal injury or missing persons, enter 6000 days. For all other injuries enter the number of calendar days of disability, or time charges using the schedule of charges, Table 1, Appendix I. Whenever the schedule of charges is used the actual number of calendar days of disability is not entered.

Block 15. Weather/Natural Disaster. If a factor, describe weather conditions or natural disaster which contributed to the injury.

Block 16. Light Conditions at Site. Describe outside or internal lighting conditions, as applicable, existing at the immediate site and time of accident.

Block 17. Description of Events. Enter narrative description of circumstances and events which directly or indirectly led to the injury, physical impairment or death. Include sufficient information to clarify or expand upon the character and scope of data to be entered in blocks 18 through 25 of the report. Accidental injury/death reports in all cases resulting from a ship accident will reference the applicable ship accident report serial in this block. Include in this block, as appropriate, comments on the following:

a. Time injured person first seen by medical officer/representative.
b. Disposition of injured person; i.e. treated and retained aboard or transferred to another ship (military personnel) or transferred to a hospital for treatment (military and civilian personnel).
c. In cases of exposure to toxic fumes/chemical poisons, describe type of substance, concentration and type of exposure.
d. Describe additional causative/contributing factors not described in blocks 20 through 25 and indicate (D) for a definite cause, (S) for a suspected cause and (P) for condition present but not a factor. Enter name, rank/rate or grade and address of witnesses to the accident. If none, so indicate.

Block 18. Kind of Injury. Enter words from Block 18 (on reverse side of this sheet) which best describes nature of injury.

Block 19. Body Part Injured. Enter word(s) from block 19 (on reverse side of this sheet) which best describes body part affected by nature of injury

Block 20. Source of Injury. Enter object or environment from block 20 (on reverse side of this sheet) which best describes source of injury. (NOTE: A direct logical relationship between "Source of Injury" and "Kind of Injury" must be established).

Block 21. Kind of Accident. Enter action, motion or type of contact from block 21 (on reverse side of this sheet) which best describes means by which injured person came in contact with previously selected "Source of Injury". (NOTE: A direct logical relationship between the "Source of Injury" and "Kind of Accident" must be established.)

Block 22. Hazardous Condition. Enter the condition from Block 22 (on reverse side of this sheet) which best describes the hazardous condition which permitted or occasioned occurrence of previously selected "kind of Accident". (NOTE: A direct logical relationship between "Kind of Accident", "Hazardous Condition" and "Agency of Accident", which is to follow, must be established).

Block 23. Agency (and Agency Part) of Accident. Enter the object or environment from Block 20 (on reverse side of this sheet) which best describes the agency to which the hazardous condition applies. In addition, describe the part of the agency which is unsafe. For instance, if the agency is a table saw from which the blade guard has been removed, enter the words "cross cut saw - blade." In some agencies such as a length of pipe, rope, lumber, etc., no agency part is required to be named. The rule for agency part is - if corrective or preventive action for the part involved is different from the action on any other part of the agency, name the agency part involved. (NOTE: A direct logical relationship between "Hazardous Condition" and "Agency of Accident" must be established). If there is no hazardous condition there can be no agency or agency part of accident, and all three items shall be described as "Not Applicable".

Block 24. Unsafe Act. Enter the act or ommission from Block 24 (on reverse side of this sheet) which best describes unsafe act which permitted or caused occurrence of previously named kind of accident. (NOTE: A direct logical relationship between "Unsafe Act" and "Kind of Accident" must be established).

Block 25. Unsafe Personal Factor. Enter the reason from Block 25 (on reverse side of this sheet) which best describes the unsafe personal factor which led to the "Unsafe Act" or contributed to the injury. (NOTE: If there was an unsafe act committed, an unsafe personal factor should always be selected. If no unsafe act was committed there may still, however, be an unsafe personal factor which contributed to the accident).

Block 26. Reason for Being on Government Property. Self-explanatory.

Block 27. Corrective Action Taken/Recommended. List specific remedial actions which have been or should be taken to prevent recurrence of similar injury. If an entry of "unknown" or "none" seems appropriate, an explanation shall be given as to why corrective action can not be recommended. Specify whether actions have been taken or are only recommended. If the latter, what action is expected?

Blocks 28 through 30. First Signature Line. Report is to be signed and dated by the individual who prepared the report to this point.

Block 31. Review and Comments of Safety Officer or Commanding Officer. Additional recommendations may be made if appropriate.

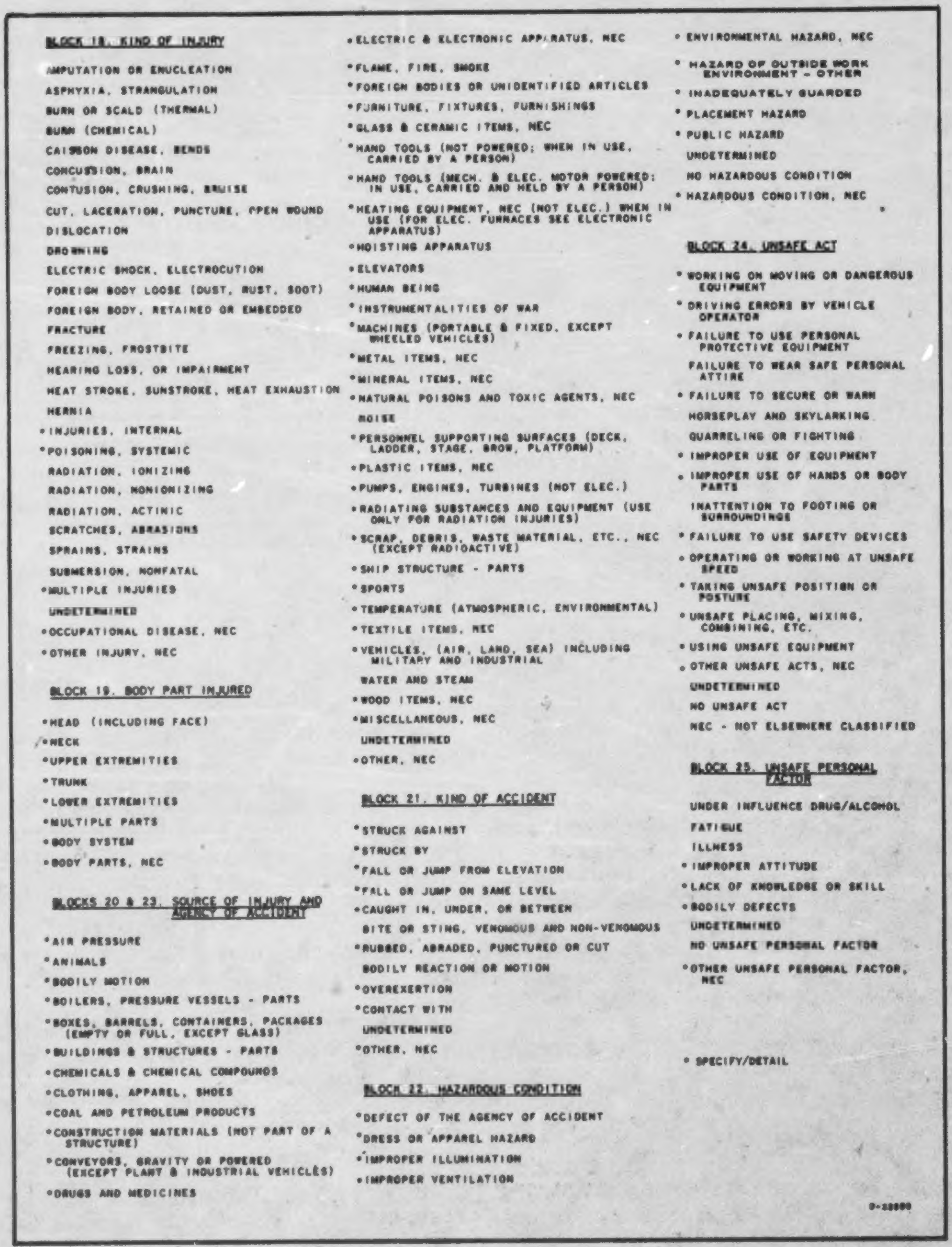
Blocks 32 through 34. Second Signature Line. Self-explanatory.

The remainder of the report form will only be filled out in those instances where the injury/death to the military member is reportable to JAG.

a. Blocks 1-34. Prepared in accordance with above instructions.
b. Blocks 35-50. Self-explanatory.
c. Blocks 35 through 40, 42, and 44 through 46 shall be completed and signed by the medical officer on the basis of his observation or examination of the injured or deceased member and information then available to him.
d. Blocks 41, 43 and 47 through 50 shall be completed and signed by the commanding officer on the basis of his investigation (or by an officer authorized and directed by the commanding officer to investigate the accident and sign the report by direction).

29.52.3

Figure 2-11.—Instructions for Accidental Injury/Death Report (front).



BLOCK 18. KIND OF INJURY

AMPUTATION OR ENUCLEATION
ASPHYXIA, STRANGULATION
BURN OR SCALD (THERMAL)
BURN (CHEMICAL)
CAISSON DISEASE, BENDS
CONCUSSION, BRAIN
CONTUSION, CRUSHING, BRUISE
CUT, LACERATION, PUNCTURE, OPEN WOUND
DISLOCATION
DROWNING
ELECTRIC SHOCK, ELECTROCUTION
FOREIGN BODY LOOSE (DUST, RUST, SOOT)
FOREIGN BODY, RETAINED OR EMBEDDED
FRACTURE
FREEZING, FROSTBITE
HEARING LOSS, OR IMPAIRMENT
HEAT STROKE, SUNSTROKE, HEAT EXHAUSTION
HERNIA
•INJURIES, INTERNAL
•POISONING, SYSTEMIC
RADIATION, IONIZING
RADIATION, NONIONIZING
RADIATION, ACTINIC
SCRATCHES, ABRASIONS
SPRAINS, STRAINS
SUBMERSION, NONFATAL
•MULTIPLE INJURIES
UNDETERMINED
•OCCUPATIONAL DISEASE, NEC
•OTHER INJURY, NEC

BLOCK 19. BODY PART INJURED

•HEAD (INCLUDING FACE)
•NECK
•UPPER EXTREMITIES
•TRUNK
•LOWER EXTREMITIES
•MULTIPLE PARTS
•BODY SYSTEM
•BODY PARTS, NEC

BLOCKS 20 & 23. SOURCE OF INJURY AND AGENCY OF ACCIDENT

•AIR PRESSURE
•ANIMALS
•BODILY MOTION
•BOILERS, PRESSURE VESSELS - PARTS
•BOXES, BARRELS, CONTAINERS, PACKAGES (EMPTY OR FULL, EXCEPT GLASS)
•BUILDINGS & STRUCTURES - PARTS
•CHEMICALS & CHEMICAL COMPOUNDS
•CLOTHING, APPAREL, SHOES
•COAL AND PETROLEUM PRODUCTS
•CONSTRUCTION MATERIALS (NOT PART OF A STRUCTURE)
•CONVEYORS, GRAVITY OR POWERED (EXCEPT PLANT & INDUSTRIAL VEHICLES)
•DRUGS AND MEDICINES
•ELECTRIC & ELECTRONIC APPARATUS, NEC
•FLAME, FIRE, SMOKE
•FOREIGN BODIES OR UNIDENTIFIED ARTICLES
•FURNITURE, FIXTURES, FURNISHINGS
•GLASS & CERAMIC ITEMS, NEC
•HAND TOOLS (NOT POWERED; WHEN IN USE, CARRIED BY A PERSON)
•HAND TOOLS (MECH. & ELEC. MOTOR POWERED: IN USE, CARRIED AND HELD BY A PERSON)
•HEATING EQUIPMENT, NEC (NOT ELEC.) WHEN IN USE (FOR ELEC. FURNACES SEE ELECTRONIC APPARATUS)
•HOISTING APPARATUS
•ELEVATORS
•HUMAN BEING
•INSTRUMENTALITIES OF WAR
•MACHINES (PORTABLE & FIXED, EXCEPT WHEELED VEHICLES)
•METAL ITEMS, NEC
•MINERAL ITEMS, NEC
•NATURAL POISONS AND TOXIC AGENTS, NEC
NOISE
•PERSONNEL SUPPORTING SURFACES (DECK, LADDER, STAGE, BROW, PLATFORM)
•PLASTIC ITEMS, NEC
•PUMPS, ENGINES, TURBINES (NOT ELEC.)
•RADIATING SUBSTANCES AND EQUIPMENT (USE ONLY FOR RADIATION INJURIES)
•SCRAP, DEBRIS, WASTE MATERIAL, ETC., NEC (EXCEPT RADIOACTIVE)
•SHIP STRUCTURE - PARTS
•SPORTS
•TEMPERATURE (ATMOSPHERIC, ENVIRONMENTAL)
•TEXTILE ITEMS, NEC
•VEHICLES, (AIR, LAND, SEA) INCLUDING MILITARY AND INDUSTRIAL
WATER AND STEAM
•WOOD ITEMS, NEC
•MISCELLANEOUS, NEC
UNDETERMINED
•OTHER, NEC

BLOCK 21. KIND OF ACCIDENT

•STRUCK AGAINST
•STRUCK BY
•FALL OR JUMP FROM ELEVATION
•FALL OR JUMP ON SAME LEVEL
•CAUGHT IN, UNDER, OR BETWEEN
BITE OR STING, VENOMOUS AND NON-VENOMOUS
•RUBBED, ABRADED, PUNCTURED OR CUT
BODILY REACTION OR MOTION
•OVEREXERTION
•CONTACT WITH
UNDETERMINED
•OTHER, NEC

BLOCK 22. HAZARDOUS CONDITION

•DEFECT OF THE AGENCY OF ACCIDENT
•DRESS OR APPAREL HAZARD
•IMPROPER ILLUMINATION
•IMPROPER VENTILATION
•ENVIRONMENTAL HAZARD, NEC
•HAZARD OF OUTSIDE WORK ENVIRONMENT - OTHER
•INADEQUATELY GUARDED
•PLACEMENT HAZARD
•PUBLIC HAZARD
UNDETERMINED
NO HAZARDOUS CONDITION
•HAZARDOUS CONDITION, NEC

BLOCK 24. UNSAFE ACT

•WORKING ON MOVING OR DANGEROUS EQUIPMENT
•DRIVING ERRORS BY VEHICLE OPERATOR
•FAILURE TO USE PERSONAL PROTECTIVE EQUIPMENT
FAILURE TO WEAR SAFE PERSONAL ATTIRE
•FAILURE TO SECURE OR WARN
HORSEPLAY AND SKYLARKING
QUARRELING OR FIGHTING
•IMPROPER USE OF EQUIPMENT
•IMPROPER USE OF HANDS OR BODY PARTS
INATTENTION TO FOOTING OR SURROUNDINGS
•FAILURE TO USE SAFETY DEVICES
•OPERATING OR WORKING AT UNSAFE SPEED
•TAKING UNSAFE POSITION OR POSTURE
•UNSAFE PLACING, MIXING, COMBINING, ETC.
•USING UNSAFE EQUIPMENT
•OTHER UNSAFE ACTS, NEC
UNDETERMINED
NO UNSAFE ACT
NEC - NOT ELSEWHERE CLASSIFIED

BLOCK 25. UNSAFE PERSONAL FACTOR

UNDER INFLUENCE DRUG/ALCOHOL
FATIGUE
ILLNESS
•IMPROPER ATTITUDE
•LACK OF KNOWLEDGE OR SKILL
•BODILY DEFECTS
UNDETERMINED
NO UNSAFE PERSONAL FACTOR
•OTHER UNSAFE PERSONAL FACTOR, NEC

• SPECIFY/DETAIL

[illegible]

29.52.4

Figure 2-12.—Instructions for Accidental Injury/Death Report (back).

working at an unsafe speed, that is, too fast or too slow? Was a safety device made inoperative, that is, blocked out or removed? Was a load made unsafe, or were tools or equipment put in an unsafe place where they would fall? Did someone fail to wipe oil, water, grease, paint, or some other substance from working surfaces? Did the injured man take an unsafe position or posture? Did he lift with a bent back or while in an awkward position? Did he lift jerkily? Was he using improper means of ascending or descending? Was the injury caused by failure to wear the provided safe attire or personal protective devices, such as goggles, gloves, masks, aprons, or safety shoes?

4. UNSAFE PERSONAL FACTOR. Was the man absentminded or inattentive? Did he fail to understand instructions, regulations, or safety rules? Did he willfully disregard instructions or safety rules? Was he unaware of safe practices, unpracticed, or unskilled? Was he unable to recognize or appreciate the hazards? Did he have a bodily defect, such as poor eyesight, defective hearing, or hernia?

5. TYPE OF INJURY. Did he sustain a cut, bruise, sprain, strain, hernia, or fracture?

6. PART OF BODY AFFECTED. Did the injury involve an arm, leg, ribs, feet, fingers, head, or other part of the body?

These categories suggest some of the things (not all) a supervisor must investigate and report when accidents occur. Remember there are some questions in these categories that request medical information which can only be obtained from a doctor. Each accident is different, and each should be investigated and judged individually. Do not jump to conclusions. Start each investigation with an open mind. The most important reason for any accident investigation is prevention of a similar accident.

FIRST AID

First aid is the immediate and temporary care given the victim of an accident before treatment can be administered by trained medical personnel. Your work may frequently be performed in areas where medical personnel are not readily available. It is important, therefore, for you and other CE's to be well trained in first aid procedures.

GENERAL

Place the victim in a prone position (lying flat), with his head level with the body until treatment requires movement. Check for hemorrhage, stoppage of breathing, wounds, fractures, dislocations, and other injuries. If clothing must be removed, cut it away—do not move the injured person. Do not permit the victim to see his injury and keep onlookers away from the scene.

Provide IMMEDIATE treatment for serious bleeding, stoppage of breathing, and poisoning—in that order. Keep the victim warm and treat for shock. Call a medical officer and give the following information: (1) the location of the victim; (2) the nature, cause, and probable extent of the injury; (3) available supplies; and (4) the type of first aid being given.

Unless it is absolutely necessary, to avoid complicating the injury do not hurry while moving the injured person—and KEEP CALM.

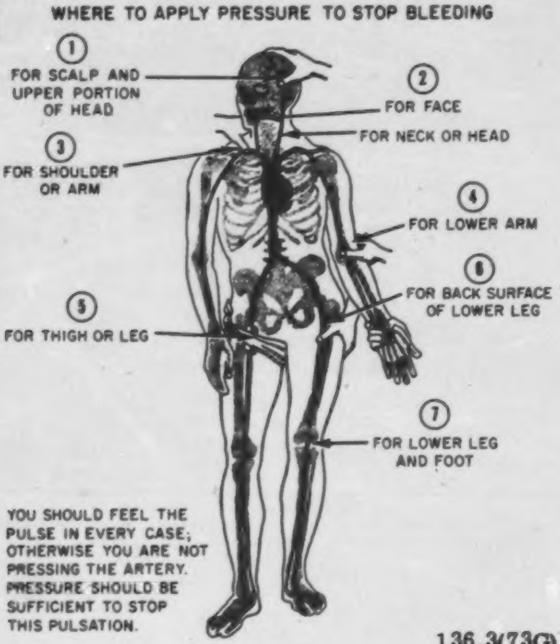
Bleeding

A break in the skin may be subject to two primary dangers: serious bleeding and/or infection. When the bleeding is severe, stop it as rapidly as possible by applying a thick layer of gauze or clean folded handkerchiefs against the bleeding point and applying firm pressure with your hand. Elevate the injured part if possible.

If the bleeding is not controlled in this manner, apply hand pressure at a pressure point.

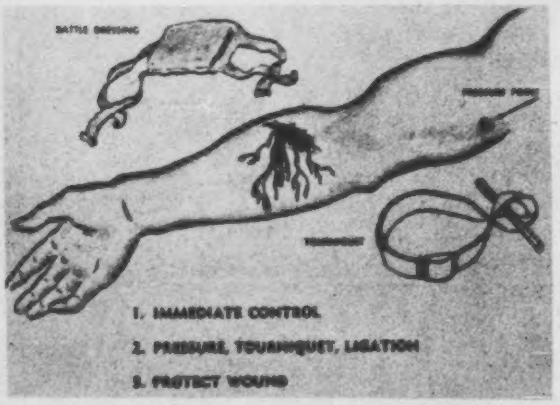
A PRESSURE POINT is a point between the heart and the wound where pressure may be applied to the artery to close off the blood supply to the wounded part. The main pressure points are shown in figure 2-13.

If a pressure dressing or hand pressure does not control the hemorrhage, a tourniquet (fig. 2-14) may be used. The tourniquet should be placed above the wound and as near it as possible. (Tourniquets are used only on extremities.) To be effective, the tourniquet must


WHERE TO APPLY PRESSURE TO STOP BLEEDING
①
FOR SCALP AND UPPER PORTION OF HEAD
②
FOR FACE
FOR NECK OR HEAD
③
FOR SHOULDER OR ARM
④
FOR LOWER ARM
⑥
FOR BACK SURFACE OF LOWER LEG
⑤
FOR THIGH OR LEG
⑦
FOR LOWER LEG AND FOOT
YOU SHOULD FEEL THE PULSE IN EVERY CASE; OTHERWISE YOU ARE NOT PRESSING THE ARTERY. PRESSURE SHOULD BE SUFFICIENT TO STOP THIS PULSATION.

136.3(73G)

Figure 2-13.—Seven pressure points to stop arterial bleeding.


BATTLE DRESSING
1. IMMEDIATE CONTROL
2. PRESSURE, TOURNIQUET, LIGATION
3. PROTECT WOUND

136.2:4

Figure 2-14.—Measures for control of arterial hemorrhage.

be tightened until the arterial flow stops, but no tighter. Excessive pressure will cause damage to the tissue beneath it. However, if the tourniquet is not applied tightly enough and only stops the venous flow, it may actually increase the loss of arterial blood.

The tourniquet should never be covered, and the time it was applied must be noted on the casualty tag or on a tag attached to the tourniquet. A properly applied tourniquet can be retained safely for 2 or 3 hours without being loosened. In cold weather it can be left on even longer. It is best, especially among those with limited experience and knowledge in the treatment of shock and hemorrhage, to leave the tourniquet on until the hemorrhage can be controlled by other means. A TOURNIQUET SHOULD NOT BE USED UNLESS THE HEMORRHAGE CANNOT BE CONTROLLED BY ANY OTHER MEANS. After the bleeding is controlled, treat the victim for shock.

Shock Symptoms and Treatment

Every injured person is potentially in shock, since shock usually occurs whenever there is severe injury of any part of the body. Start treatment for shock immediately; do not wait for symptoms to develop. Some symptoms are shown in figure 2-15.

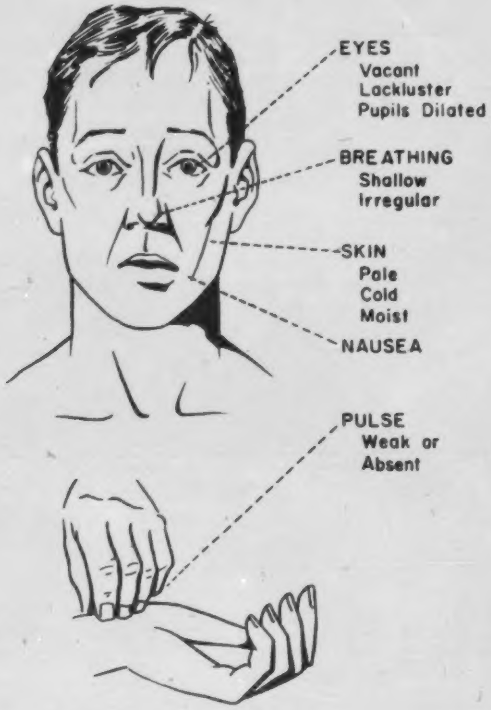
In treating a victim for shock, try to retain the victim's body heat. Place blankets or clothing underneath as well as on top of the victim (fig. 2-16). Remove cold or wet clothing avoiding unnecessary exposure, and keep the victim's head lower than his feet unless he has a head or chest injury. If he is conscious, provide him with small doses of hot coffee or tea if available, and he is not nauseated or vomiting. Remember—shock is easier to prevent than to cure.

EMERGENCY PROCEDURES

Resuscitation is a general term which covers all of the measures taken to restore life or consciousness to one apparently dead. These measures include ARTIFICIAL RESPIRATION to restore normal respiratory functions and CLOSED CHEST CARDIAC MASSAGE to restore normal heart beat.

Artificial Respiration

Begin artificial respiration IMMEDIATELY. Seconds, rather than minutes, count. The person nearest the victim should start the resuscitation without delay and call or send others for assistance and medical aid. The only logical permissible delay is that required to free the man from his contact with electricity in the quickest safest way. This step, while it must



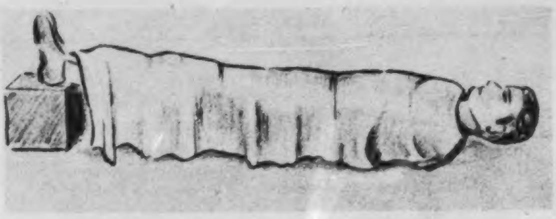
136.5

Figure 2-15.—Look for these symptoms in shock.

be taken quickly, must be done with great care; otherwise, there might be two victims instead of one.

> WARNING
>
> DO NOT attempt to administer first aid or come into physical contact with an electric shock victim before the voltage is cut off, or if the voltage cannot be turned off immediately, before the victim has been removed from the live conductor.

To aid a victim of electric shock after removing him from contact with electricity, immediately apply mouth-to-mouth or mouth-to-nose artificial respiration (figs. 2-17 and 2-18), or both if it is a child or a person with



136.6

Figure 2-16.—Patient in position for treatment of shock.

ARTIFICIAL RESPIRATION

MOUTH-TO-MOUTH OR MOUTH-TO-NOSE RESCUE BREATHING

① **PLACE CASUALTY ON BACK IMMEDIATELY**
DON'T WASTE TIME MOVING TO A BETTER PLACE, LOOSENING CLOTHING, OR DRAINING WATER FROM LUNGS.

② **QUICKLY CLEAR MOUTH AND THROAT**
REMOVE MUCUS, FOOD, DENTURES, CHEWING GUM, AND OTHER OBSTRUCTIONS.

③ **TILT HEAD BACK AS FAR AS POSSIBLE**
THE HEAD SHOULD BE IN A "CHIN-UP" OR "SNIFF" POSITION AND THE NECK STRETCHED.

④ **LIFT LOWER JAW FORWARD**
GRASP JAW BY PLACING THUMB INTO CORNER OF MOUTH. DO NOT HOLD OR DEPRESS TONGUE.

⑤ **PINCH NOSE SHUT OR SEAL MOUTH**
PREVENT AIR LEAKAGE.

⑥ **OPEN YOUR MOUTH WIDE AND BLOW**
TAKE A DEEP BREATH AND BLOW FORCEFULLY (EXCEPT FOR BABIES) INTO MOUTH OR NOSE UNTIL YOU SEE CHEST RISE.

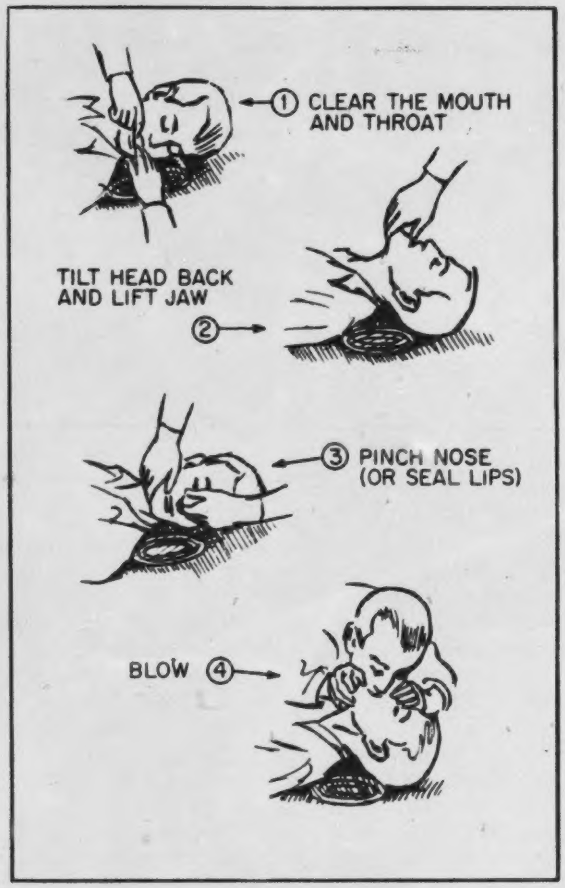
⑦ **LISTEN FOR EXHALATION**
QUICKLY REMOVE YOUR MOUTH WHEN CHEST RISES. LIFT JAW HIGHER IF VICTIM MAKES SNORING OR GURGLING SOUNDS.

⑧ **REPEAT STEPS SIX AND SEVEN 12 TO 20 TIMES PER MINUTE**
CONTINUE UNTIL VICTIM BEGINS TO BREATHE NORMALLY.

* **FOR INFANTS SEAL BOTH MOUTH AND NOSE WITH YOUR MOUTH**
BLOW WITH SMALL PUFFS OF AIR FROM YOUR CHEEKS.

4.224

Figure 2-17.—Procedure for artificial respiration.


① CLEAR THE MOUTH AND THROAT
TILT HEAD BACK AND LIFT JAW
②
③ PINCH NOSE (OR SEAL LIPS)
BLOW ④

4.224

Figure 2-18.—Mouth-to-mouth respiration.

a small face. If there is no pulse, immediately apply heart massage also (fig. 2-19).

Don't waste precious seconds carrying the victim from cramped, wet, or isolated locations or to loosen his clothing. Revival chances decrease rapidly if not started within 3 minutes after shock.

To eliminate physical contact from mouth-to-mouth artificial respiration, an oropharyngeal airway may be used if available; if not, a cloth or handkerchief may be placed over the victim's face. If assistance is available, take turns breathing into the victim and massaging his heart.

External Cardiac Massage

If the victim has suffered an electric shock and has no heart beat, he has had a cardiac arrest. This is demonstrated by complete absence of any pulse at the wrist or the neck, dilated pupils, and weak or stopped respiration. The victim may appear to be dead.

The object of closed chest cardiac massage is to squeeze the heart through the chest wall, thereby emptying it to create a peripheral pulse. This must be done about 60 times each minute.

DIRECTIONS.—Place the victim on his back on the floor or other firm surface. Expose his chest. Kneel beside victim; feel for lower end of his breastbone; place one hand across the breastbone so the heel of your hand covers the lower part; place your other hand on top of the first so that the fingers point toward the victim's neck (fig. 2-19).

With arms nearly straight, rock forward so that a controlled amount of your body weight is transmitted through your arms and hands to the breastbone. The amount of pressure to apply will vary with the victim. It should be applied as smoothly as possible. With an adult, the chest wall should be depressed 2 to 3 inches for the first pressure application and 1 to 1-1/2 inches for each additional pressure application.

Repeat application of pressure about 60 to 80 times per minute. An assistant should be ventilating the victim's lungs preferably with pure oxygen under intermittent positive pressure; otherwise with mouth-to-mouth resuscitation. However, closed chest massage will cause some ventilation of the lungs. Therefore, if you are alone, you must concentrate on the massage until help arrives.

Direct other assistants, when available, to keep checking the victim's pulse. Use the least pressure that will secure an effective pulse beat. The pupils will become smaller when effective cardiac massage is being performed. Pause occasionally to determine if a spontaneous heart beat has returned.

PRECAUTIONS.—Make every effort to keep the hands positioned as described in order to prevent injuries to the liver, ribs, or other vital organs. Since the heart cannot recover unless supplied with oxygenated blood, it is

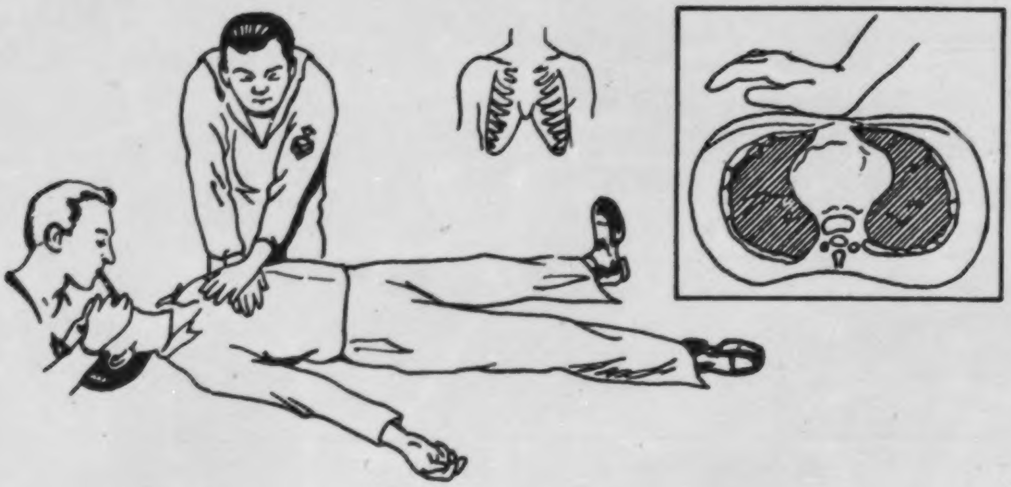


Figure 2-19.—Cardiac massage.

necessary to accompany cardiac massage with mouth-to-mouth or mouth-to-nose artificial respiration. When there is only one operator, the cardiac massage must be interrupted every half minute or so to institute rapid mouth-to-mouth breathing for three or four respirations.

BURNS

The principal dangers from burns are shock and infection. All casualty care measures must be directed toward combating shock, relieving the casualty's pain, and preventing infection.

Classification of Burns

Burns are classified in two ways; their causes and the depth of skin damage.

Thermal burns are the direct result of heat, such as fire, scalding, sun or explosion blast. Chemical burns are produced by chemical action such as battery acid on tissues. Electrical burns may be caused by electrical current passing through tissues or a superficial wound caused by electrical flash.

Burns may be classified as first, second, or third degree, based on the depth of skin damage (fig. 2-20). First-degree burns are characterized only by reddening of the skin. Second-degree burns are characterized by blistering of the skin, either early or late. They are the most painful type of burn. The complete thickness of the skin is not destroyed. Third-degree burns are characterized by complete destruction of the skin with charring and cooking of the deeper tissues. This is the most serious type of burn, for it produces a deeper state of shock and more permanent damage and disfigurement. It is not as painful as a second-degree burn because the sensory nerve endings have been destroyed.

Emergency Treatment

The degree of the burn, as well as the skin area involved, determines the procedures used in treatment of burns. Involvement of large skin areas requires a different approach than small areas. To estimate the amount of skin area affected, use fig. 2-21.

As a guideline, consider that a burn of more than 20 percent of the body surface endangers life. The old or the very young victim does not tolerate burn injuries well. Without adequate treatment, a burn of more than 30 percent of the body surface is usually fatal to adults.

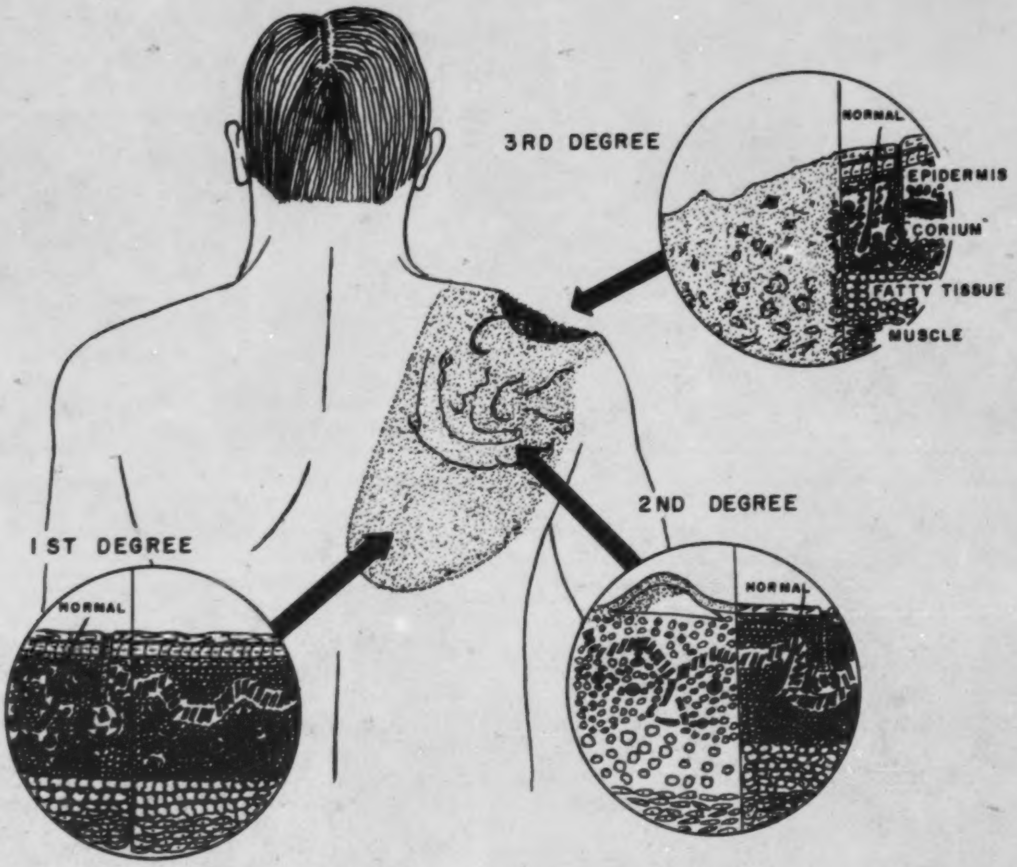


Figure 2-20.—Types and degrees of burns.

If time and facilities permit caring for superficial burns, the area should be cleaned with soap and water. A simple sterile dressing of fine-mesh, dry gauze is then applied over the area to protect it from infection and mechanical trauma.

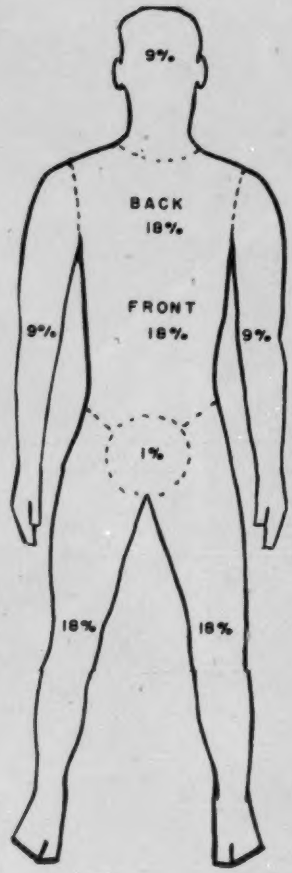
Based on field level casualty treatment conditions, superficial burns include first-degree burns and lesser second-degree burns, which need little attention beyond self-care. Treatment of the more serious second-degree burns and third-degree burns is the subject of the following discussion.

When emergency treatment of deep burn casualties is required, treat the victim for shock first. Make him as comfortable as possible, and protect him from cold, excessive heat, and rough handling.

The loss of body fluids is the main factor in burn shock. Start oral therapy gradually at first by giving him small amounts of hot coffee or tea frequently. These drinks, or fruit juice or sugar water, must be given only if the victim is conscious, able to swallow, and has no internal injuries.

Pain is closely allied to the degree of shock, and should be relieved as soon as possible.

To enable personnel trained in the management of burns to determine the type of treatment, no medication should be applied to burns during emergency treatment.



136.31
Figure 2-21.—Computing body surface.

After the victim has been treated for pain and shock, a compress and bandage may be applied to protect the burned area. If a Universal protective dressing is not available, fine-mesh gauze may be substituted. Constricting articles of clothing and ornaments should be cut away or removed, and the burned area should be elevated and immobilized.

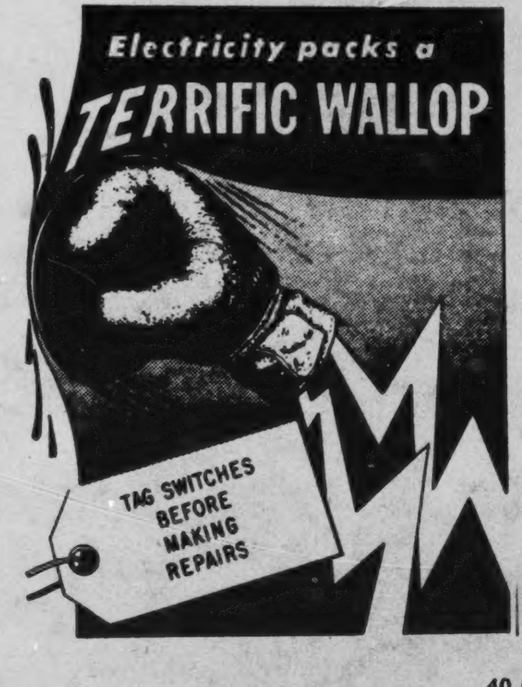
Victims with extensive deep burns must be evacuated to a medical facility for treatment as rapidly as possible. Pain should be alleviated and shock must be controlled before and during evacuation.

Debris and loose clothing must be removed from burned areas to prevent irritation while the victim is being treated and transported. Clothing that sticks to the burn may be cut around the burn and the adhering cloth allowed to remain until it can be removed at the medical facility. The area of the burn is usually sterile; therefore, care should be taken not to contaminate it.

Remember—in electric shock, the burn may have to be temporarily ignored while resuscitative measures are carried out. Treatment for chemical burns varies depending upon the agent that caused the burns. Flooding the affected area caused by the burn with large amounts of preferably clean, fresh, cool water will minimize damage provided that not too much force is used upon application. Ice water treatment is an effective pain reducer, if available.

Become familiar with the STANDARD FIRST AID TRAINING COURSE, NAVPERS 10081-B. Your prompt and correct response to an emergency may save a life.

Above all, remember your A B C's: Always Be Careful. (See fig. 2-22.)



40.67
Figure 2-22.—Safety.

CHAPTER 3

BLUEPRINTS, DIAGRAMS AND SCHEMATICS

Diagrams and schematics are maps which indicate the location of circuits and circuit connections of electrical installations and equipment. When properly utilized, they are an invaluable aid in troubleshooting or in determining faults in an electrical circuit. Locating and repairing faults are some of the most important work assignments you will have. You will also be required to install new circuits or repair old construction.

Blueprints are reproductions of the working drawings of schematics. The proper use of blueprints pays dividends in many ways. For example, blueprints will save many man-hours of "sight-traveling" cables as you seek malfunctions or an unknown termination point.

The ships, planes, buildings, and guns of the Navy were built from plans on blueprints and they are operated, checked, and maintained according to information found on those blueprints. When mechanisms fail in service or are damaged in battle, blueprints are used to aid the repairman. When new parts are to be made or the system is expanded, blueprints provide the necessary information. Remember, too, that much planning and manpower and material estimating are based on the information contained in these blueprints. This chapter discusses the function and care of blueprints, and the importance of being able to read and work from them.

BLUEPRINT READING

The term "blueprint reading" refers to the ability to express the meanings conveyed in drawings, whether the drawings are actually blueprints or not. Be aware that all blueprints are not blue in color, but a drawing of any color which delineates a master or key plan. An important reference is the basic Navy training manual Blueprint Reading and Sketching, NAVEDTRA 10077-C. If necessary, review chapters 1 through 5 of NAVEDTRA 10077-C; these chapters provide information that will aid the CE in duties involving blueprint reading.

CARE OF BLUEPRINTS

Blueprints are valuable permanent records which can be used again and again if you take care of them. Here are a few pointers on the care of prints:

1. Keep them out of sunlight to prevent fading.

2. DO NOT make pencil or crayon notations on a print without proper authority. If you should be instructed to mark a blueprint, use a crayon or pencil with appropriately colored lead. A yellow crayon provides good contrast to a blue background while ordinary black lead pencil marks are hard to see.

3. Avoid getting the prints wet or grease-smudged.

4. Keep prints stored properly so they can be located quickly the next time you need them. A standardized, accurate system of filing blueprints is necessary. This system ensures that the identifying marks appear in the same place, preferably at the top, when the prints are in vertical filing order.

FOLDING BLUEPRINTS

Most of the prints you see will already be folded properly. Your only concern will be to see that they are refolded correctly after being used. If you use prints that have not been folded at all, or that have been folded improperly, fold them in such a manner that the drawing number in the right-hand corner of the title block appears on the outside. (Some older drawings may have the drawing numbers placed in other portions of the title block.)

The method of folding prints depends upon the type and size of the filing cabinet, and the location of the identifying marks on the prints. It is preferable to place identifying marks at the top of prints when filing them vertically (upright), and at the bottom right-hand corner, when filing them flat. In some cases construction prints are stored in rolls.

PARTS OF A PRINT

The chief part of a drawing is, of course, the graphic representation of the object, whatever it may be, together with dimension lines, dimensions, symbols, and other graphic devices which explain the representation. Additional information is inscribed in the title block, the bill of materials, the scale, and the legends and notes.

Title Block

The title block (fig. 3-1) gives the title of the drawing, and the number that has been assigned to that drawing. It also indicates who prepared the drawing, who checked it, the authority under which it was issued, and the date approved.

Drawing Number

The drawing number is especially important, both for purposes of filing the blueprint, and for locating the correct drawing when it is specified on another blueprint. For example, where a number of separate buildings shown on a series of blueprints are to have identical wiring systems, cross-referencing the other drawings to one plan which shows all the details saves the labor of repeating the wiring system on every drawing.

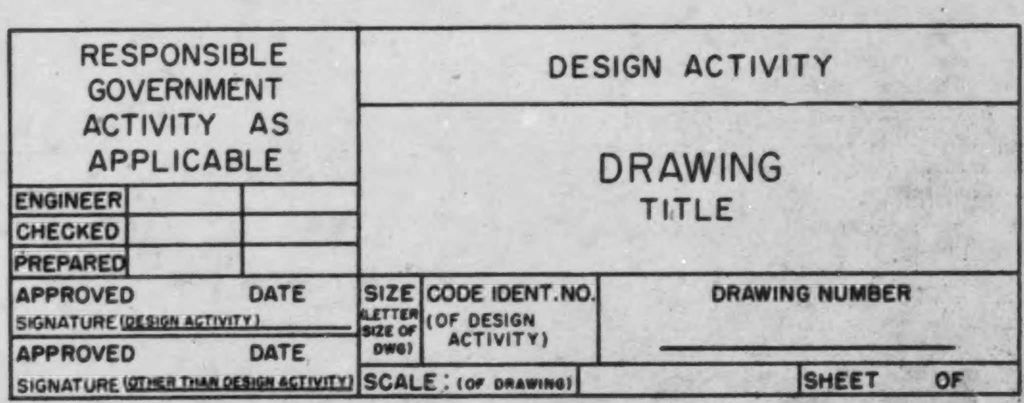
Bill of Material

The bill of material is a list of all the items required to install a particular piece of equipment or to erect a particular building. The list includes stock number, description, and quantity of each item. As you can see by referring to figure 3-2, the list is complete down to the last screw.

When equipment assemblies are received at an advanced base, it is possible for you, by checking the bill of material, to quickly determine if the items shipped are what you need for the job in hand, and whether or not they allow for changes made necessary by local conditions.

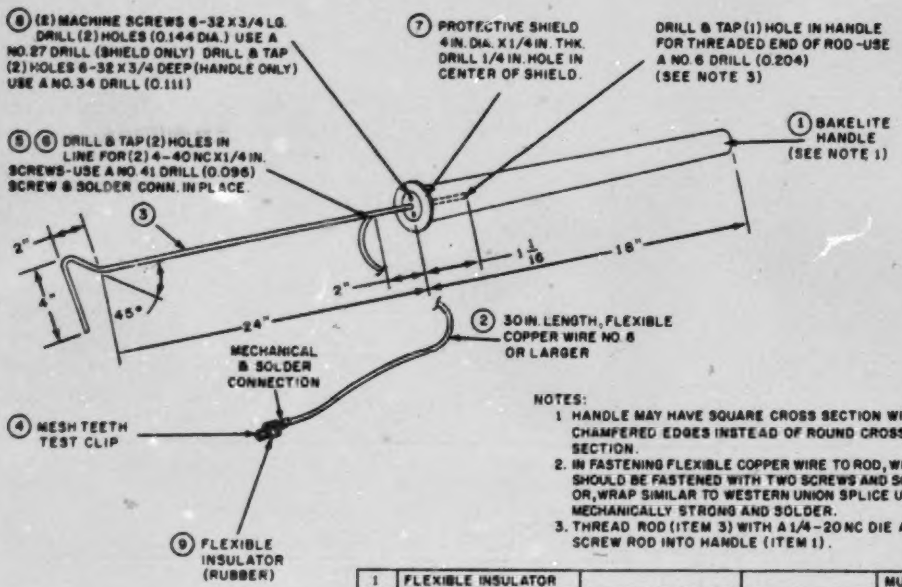
Scale

The scale of a drawing is particularly important to the Builders, but it has a practical


RESPONSIBLE GOVERNMENT ACTIVITY AS APPLICABLE
DESIGN ACTIVITY
DRAWING
TITLE
ENGINEER
CHECKED
PREPARED
APPROVED DATE
SIGNATURE (DESIGN ACTIVITY)
APPROVED DATE
SIGNATURE (OTHER THAN DESIGN ACTIVITY)
SIZE (LETTER SIZE OF DWG)
CODE IDENT. NO. (OF DESIGN ACTIVITY)
DRAWING NUMBER
SCALE: (OF DRAWING)
SHEET OF

45.159

Figure 3-1.—Title block.


⑧ (2) MACHINE SCREWS 6-32 X 3/4 LG.
DRILL (2) HOLES (0.144 DIA.) USE A NO. 27 DRILL (SHIELD ONLY) DRILL & TAP (2) HOLES 6-32 X 3/4 DEEP (HANDLE ONLY) USE A NO. 34 DRILL (0.111)
⑦ PROTECTIVE SHIELD 4 IN. DIA. X 1/4 IN. THK. DRILL 1/4 IN. HOLE IN CENTER OF SHIELD.
DRILL & TAP (1) HOLE IN HANDLE FOR THREADED END OF ROD -USE A NO. 6 DRILL (0.204) (SEE NOTE 3)
① BAKELITE HANDLE (SEE NOTE 1)
⑤ ⑥ DRILL & TAP (2) HOLES IN LINE FOR (2) 4-40 NC X 1/4 IN. SCREWS-USE A NO. 41 DRILL (0.096) SCREW & SOLDER CONN. IN PLACE.
③
2"
4"
45°
2"
1 1/16
18"
24"
② 30 IN. LENGTH, FLEXIBLE COPPER WIRE NO. 6 OR LARGER
MECHANICAL & SOLDER CONNECTION
④ MESH TEETH TEST CLIP
⑨ FLEXIBLE INSULATOR (RUBBER)

NOTES:
1 HANDLE MAY HAVE SQUARE CROSS SECTION WITH CHAMFERED EDGES INSTEAD OF ROUND CROSS SECTION.
2. IN FASTENING FLEXIBLE COPPER WIRE TO ROD, WIRE SHOULD BE FASTENED WITH TWO SCREWS AND SOLDERED OR, WRAP SIMILAR TO WESTERN UNION SPLICE UNTIL MECHANICALLY STRONG AND SOLDER.
3. THREAD ROD (ITEM 3) WITH A 1/4-20 NC DIE AND SCREW ROD INTO HANDLE (ITEM 1).

1	FLEXIBLE INSULATOR			MUELLER NO. 26	9
2	MACHINE SCREW	9Z5305-812-6647		6-32 X 3/4 IN. LG. NYLON	8
1	PROTECTIVE SHIELD	9G9330-290-3462	MIL-P-15035	BAKELITE, TYPE FBE 38 IN X 48 IN. X 1/4 IN.	7
2	MACHINE SCREW	KZ5305-637-5884		4-40 NC X 1/4 IN BRASS	6
1	SOLDER CONNECTION			SEE NOTE 3	5
1	MESH TEETH TEST CLIP			MUELLER NO. 24A OR EQUIV.	4
1	ROD	9Z9530-233-1299		1/4 IN. COPPER, BEND & FIT PER DRAWING	3
1	GROUND WIRE, 30 IN.			NO. 6 FLEXIBLE WIRE, COPPER	2
1	HANDLE, BAKELITE, 1-3/4 IN. DIA. X 18 IN.	9G9330-298-7538	MIL-P-79	BAKELITE 36 IN. LENGTH	1
QTY	NOMENCLATURE OR DECRIPTION	PART NO. OR IDENTIFICATION NO.	SPEC.	MATERIAL OR NOTE	ITEM NO.

1.1(26D)

Figure 3-2.—A bill of material on a drawing.

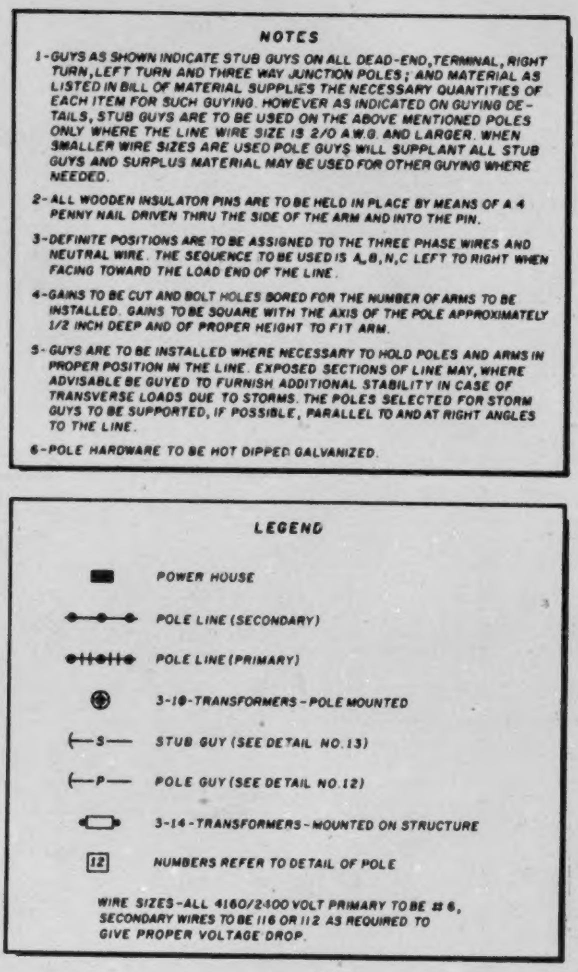
value to the Construction Electrician as well. The dimensions indicated on a drawing determine the amount of wire and conduit needed in a group of buildings. The number of poles to be erected can be figured by noting the distances between buildings.

Avoid measuring distance on a blueprint. Why? One reason is that the drawing may have been reduced in size from the original. Another is that the print may have shrunk or stretched. Whenever possible, you should READ the dimensions indicated on the drawings in preference to measuring the distance with a scale. If this is unavoidable, the graphic scale must be checked for possible expansion or shrinkage. Note especially if any details are drawn to a scale different than that of the rest of the drawing. Play it safe and READ dimensions; they always remain the same.

Notes and Legends

An example of the notes and legends which appear on a drawing is illustrated in figure 3-3. These notes contain equipment specifications, procedures for installing, and operating instructions. They may also contain explanations of parts of the drawing, and other pertinent information not included in the views themselves.

The legend lists the meaning of various symbols, abbreviations, and item numbers.



NOTES

1-GUYS AS SHOWN INDICATE STUB GUYS ON ALL DEAD-END, TERMINAL, RIGHT TURN, LEFT TURN AND THREE WAY JUNCTION POLES; AND MATERIAL AS LISTED IN BILL OF MATERIAL SUPPLIES THE NECESSARY QUANTITIES OF EACH ITEM FOR SUCH GUYING. HOWEVER AS INDICATED ON GUYING DETAILS, STUB GUYS ARE TO BE USED ON THE ABOVE MENTIONED POLES ONLY WHERE THE LINE WIRE SIZE IS 2/0 A.W.G. AND LARGER. WHEN SMALLER WIRE SIZES ARE USED POLE GUYS WILL SUPPLANT ALL STUB GUYS AND SURPLUS MATERIAL MAY BE USED FOR OTHER GUYING WHERE NEEDED.

2-ALL WOODEN INSULATOR PINS ARE TO BE HELD IN PLACE BY MEANS OF A 4 PENNY NAIL DRIVEN THRU THE SIDE OF THE ARM AND INTO THE PIN.

3-DEFINITE POSITIONS ARE TO BE ASSIGNED TO THE THREE PHASE WIRES AND NEUTRAL WIRE. THE SEQUENCE TO BE USED IS A, B, N, C LEFT TO RIGHT WHEN FACING TOWARD THE LOAD END OF THE LINE.

4-GAINS TO BE CUT AND BOLT HOLES BORED FOR THE NUMBER OF ARMS TO BE INSTALLED. GAINS TO BE SQUARE WITH THE AXIS OF THE POLE APPROXIMATELY 1/2 INCH DEEP AND OF PROPER HEIGHT TO FIT ARM.

5-GUYS ARE TO BE INSTALLED WHERE NECESSARY TO HOLD POLES AND ARMS IN PROPER POSITION IN THE LINE. EXPOSED SECTIONS OF LINE MAY, WHERE ADVISABLE BE GUYED TO FURNISH ADDITIONAL STABILITY IN CASE OF TRANSVERSE LOADS DUE TO STORMS. THE POLES SELECTED FOR STORM GUYS TO BE SUPPORTED, IF POSSIBLE, PARALLEL TO AND AT RIGHT ANGLES TO THE LINE.

6-POLE HARDWARE TO BE HOT DIPPED GALVANIZED.

LEGEND

▬	POWER HOUSE
●—●—●	POLE LINE (SECONDARY)
●‖●‖●	POLE LINE (PRIMARY)
⊕	3-1Ø-TRANSFORMERS-POLE MOUNTED
⟵S—	STUB GUY (SEE DETAIL NO. 13)
⟵P—	POLE GUY (SEE DETAIL NO. 12)
▭	3-14-TRANSFORMERS-MOUNTED ON STRUCTURE
12	NUMBERS REFER TO DETAIL OF POLE

WIRE SIZES-ALL 4160/2400 VOLT PRIMARY TO BE # 6, SECONDARY WIRES TO BE 116 OR 112 AS REQUIRED TO GIVE PROPER VOLTAGE DROP.

73.2

Figure 3-3.—Representative notes and legends.

This is a great help to the men of various ratings who may be engaged in the work, since not all of them would know the symbols well enough immediately to grasp the overall plan for the construction job. You will find legends a help when the drawings relate to a job where you must plan the laying of conduit and running of wire around plumbing fixtures, valves, duct work, or pipelines.

ELECTRICAL SYMBOLS

The number of symbols and abbreviations that may be used on drawings runs into the thousands. All draftsmen do not employ the same symbol to represent a particular item. These two facts can make blueprint reading a major task for any rating.

Fortunately, however, the Department of Defense prescribes MILITARY STANDARDS in this and other areas, which make for a high degree of uniformity in symbols employed in drawings used by the armed services. Graphic symbols for electrical diagrams are prescribed in the American National Standard Institute's Standard #Y32.9, dated 1972. Refer to table 3-1 which illustrates a number of electrical symbols used on drawings.

Use every opportunity you have to study the blueprints of the job to which you are assigned. Try to picture in your mind the item represented by each symbol. Trace the electrical circuits estimating the length of wire required for each circuit, and the locations of conductors and parts. When the lines, symbols, abbreviations, and notes make an understandable mental picture, you have learned to read an electrical drawing. Remember . . .if you do not understand what portions of the diagram mean, ask your supervising petty officer.

DIAGRAMS AND SCHEMATICS

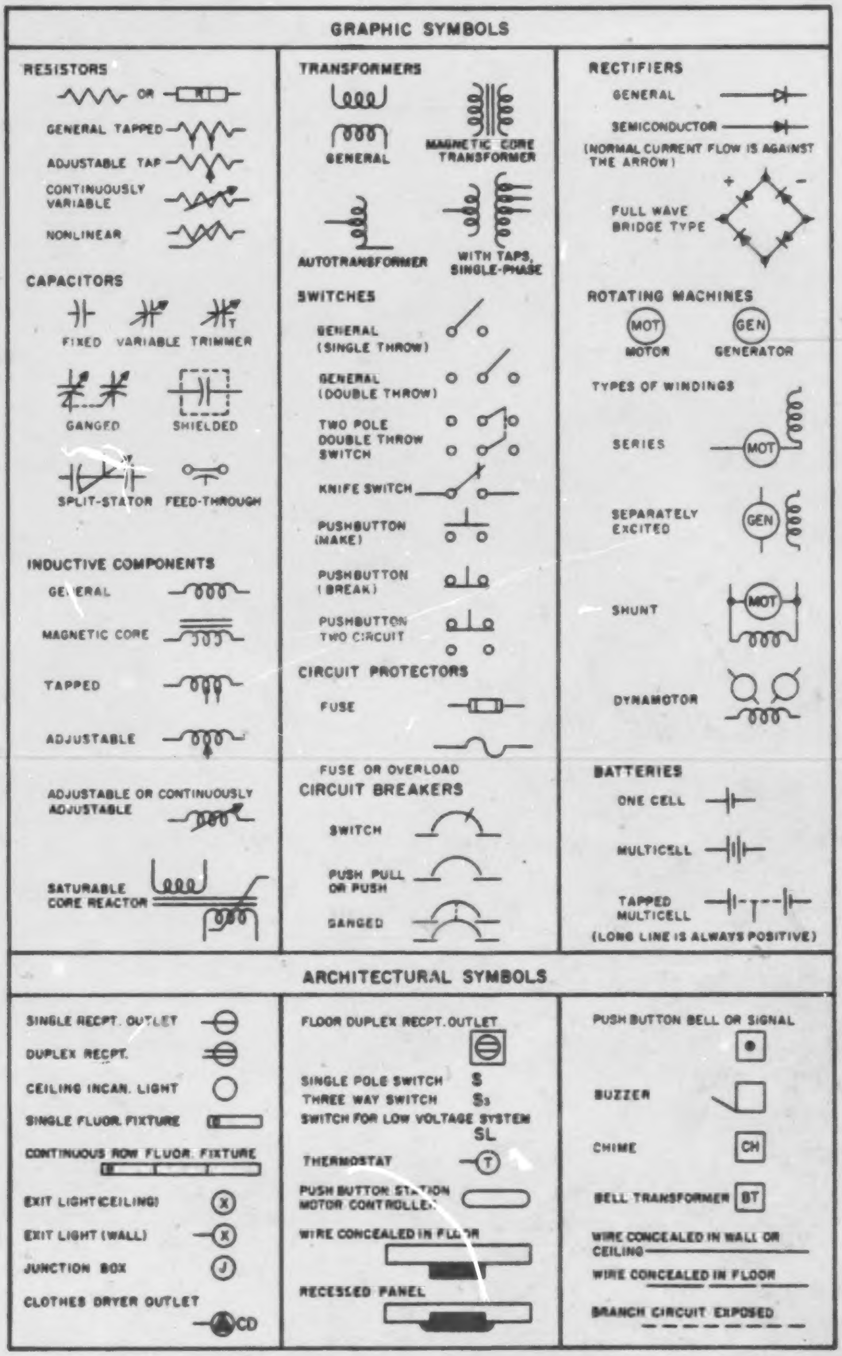
Construction Electricians, who know the trade, "talk with diagrams." When a technical question is brought up, a single diagram is often worth more than hours of discussion.

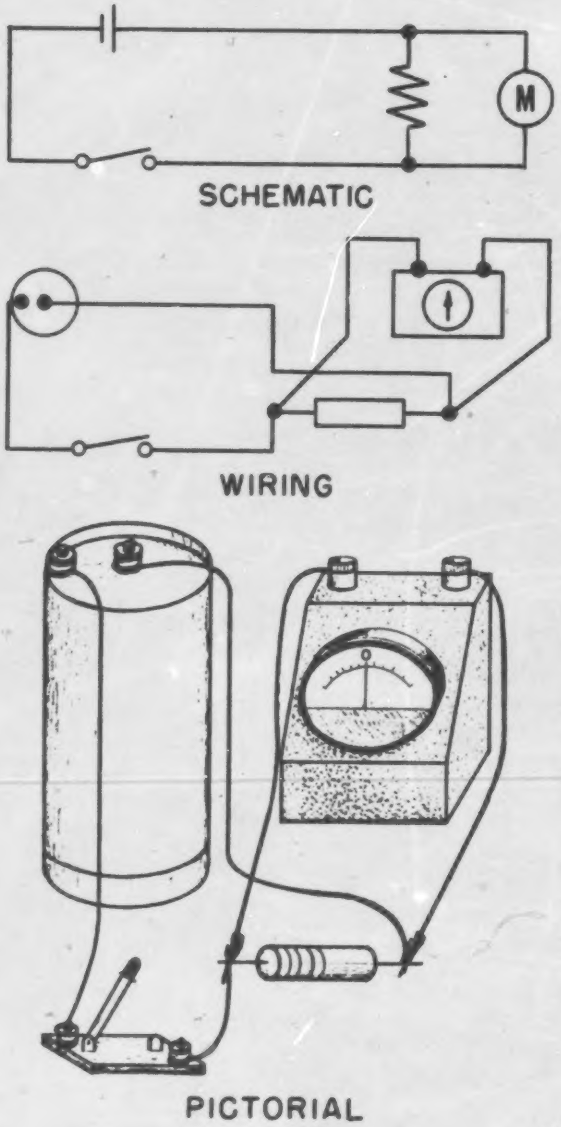
There are a number of types of electrical drawings. These may vary from wiring diagrams (scale drawings of electrical apparatus which show the exact location of all wiring and connections) to schematic diagrams and architectural plans.

In figure 3-4, a pictorial drawing, an elementary wiring diagram, and a schematic are compared. They show exactly the same thing, but they look quite different.

Let's see how diagrams prove their worth in voltage distribution, interior wiring, communications, and planning. Your work may involve you in any or all of these areas.

Table 3-1.—Electrical Symbols


GRAPHIC SYMBOLS
RESISTORS
OR
R1
GENERAL TAPPED
ADJUSTABLE TAP
CONTINUOUSLY VARIABLE
NONLINEAR
CAPACITORS
FIXED
VARIABLE
TRIMMER
T
GANGED
SHIELDED
SPLIT-STATOR
FEED-THROUGH
INDUCTIVE COMPONENTS
GENERAL
MAGNETIC CORE
TAPPED
ADJUSTABLE
ADJUSTABLE OR CONTINUOUSLY ADJUSTABLE
SATURABLE CORE REACTOR
TRANSFORMERS
GENERAL
MAGNETIC CORE TRANSFORMER
AUTOTRANSFORMER
WITH TAPS, SINGLE-PHASE
SWITCHES
GENERAL (SINGLE THROW)
GENERAL (DOUBLE THROW)
TWO POLE DOUBLE THROW SWITCH
KNIFE SWITCH
PUSHBUTTON (MAKE)
PUSHBUTTON (BREAK)
PUSHBUTTON TWO CIRCUIT
CIRCUIT PROTECTORS
FUSE
FUSE OR OVERLOAD
CIRCUIT BREAKERS
SWITCH
PUSH PULL OR PUSH
GANGED
RECTIFIERS
GENERAL
SEMICONDUCTOR
(NORMAL CURRENT FLOW IS AGAINST THE ARROW)
+
-
FULL WAVE BRIDGE TYPE
ROTATING MACHINES
MOT
MOTOR
GEN
GENERATOR
TYPES OF WINDINGS
SERIES
MOT
SEPARATELY EXCITED
GEN
SHUNT
MOT
DYNAMOTOR
BATTERIES
ONE CELL
MULTICELL
TAPPED MULTICELL
(LONG LINE IS ALWAYS POSITIVE)
ARCHITECTURAL SYMBOLS
SINGLE RECPT. OUTLET
DUPLEX RECPT.
CEILING INCAN. LIGHT
SINGLE FLUOR. FIXTURE
CONTINUOUS ROW FLUOR. FIXTURE
EXIT LIGHT (CEILING)
X
EXIT LIGHT (WALL)
X
JUNCTION BOX
J
CLOTHES DRYER OUTLET
CD
FLOOR DUPLEX RECPT. OUTLET
SINGLE POLE SWITCH
S
THREE WAY SWITCH
S3
SWITCH FOR LOW VOLTAGE SYSTEM
SL
THERMOSTAT
T
PUSH BUTTON STATION MOTOR CONTROLLER
WIRE CONCEALED IN FLOOR
RECESSED PANEL
PUSH BUTTON BELL OR SIGNAL
BUZZER
CHIME
CH
BELL TRANSFORMER
BT
WIRE CONCEALED IN WALL OR CEILING
WIRE CONCEALED IN FLOOR
BRANCH CIRCUIT EXPOSED



73.269
Figure 3-4.—Variety of diagrams.

EXTERNAL DISTRIBUTION SYSTEMS

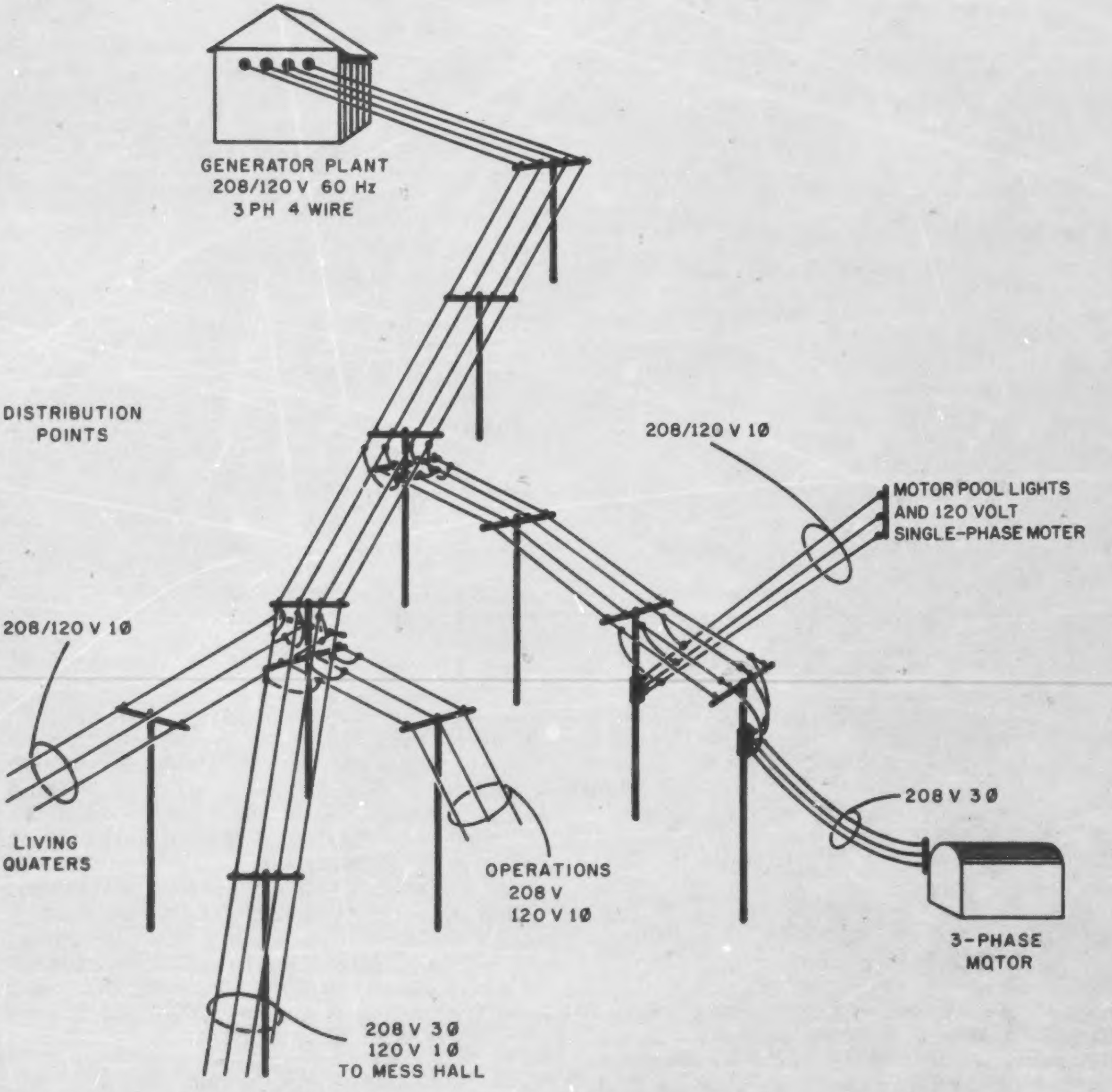
Figures 3-5 and 3-6 illustrate a pictorial and schematic view of a 3-phase/4-wire distribution system. Assume that the system has an alternator generating 208 volts. From the generating station, 3-phase/4-wire feeders carry the power overhead to the distribution points, from which primary mains branch off. One of these carries power to a lighting system and single-phase motor in a motor pool, both designed to operate on 120 volts, and to a three-phase motor designed to operate on 208 volts. The 208-volt three-phase motor is connected directly to the 208-volt three-phase main. For the lighting system and 120-volt motor, only single-phase power is necessary. Similarly, power is run to operational headquarters, living quarters, and mess hall.

A PLAN drawing is another type of drawing useful in exterior layout. The objects in views A and C of figure 3-7 are depicted as seen from directly above. In this way, the proportion and relations of the parts of the drawing to one another can be shown. The PLOT PLAN (fig. 3-7, view A) shows an area and gives the exact layout of various buildings, roads, equipment, and so on.

Figure 3-7, view A, is a plot plan showing five buildings which are to be supplied with electricity for power and lighting. An electrical layout has been superimposed. General notes (fig. 3-7, view B), one detail (fig. 3-7, view C) and section A-A (fig. 3-7, view D) of that detail are shown. The dotted line at the bottom of the drawing indicates underground ducts containing previously laid cable.

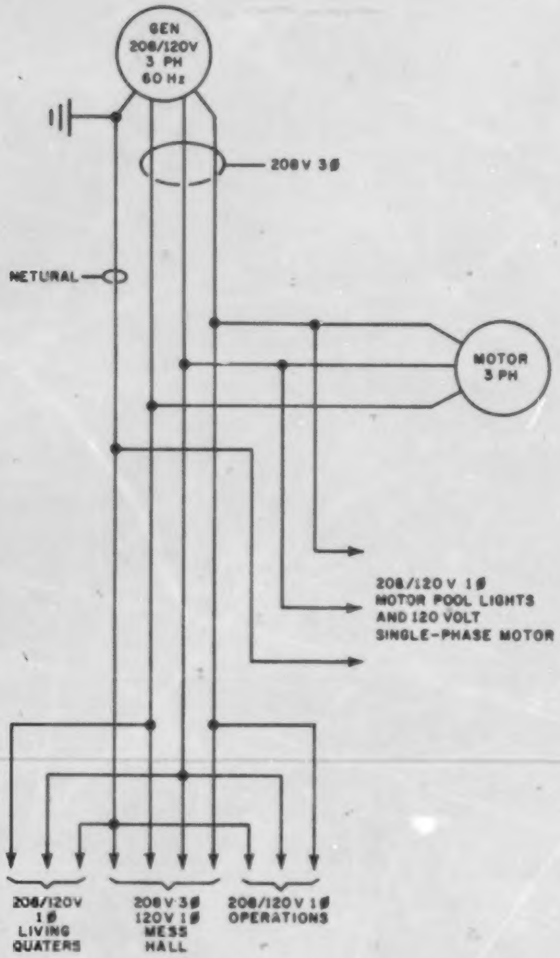
The design engineer has decided to tap the cable at manhole (M.H.) 22, and run lines from there overhead to dead end at the rear of building 126. Figure 3-7, view C, shows that lines are to be run underground from M.H. 22 to the first pole, up the pole to conductors on the pole crossarms. At building 126, lines are to be carried down the pole, regathered through a pothead into conduit again, and run underground to a concrete slab, and out through another pothead to a transformer bank. Where do you get this information? Refer to figure 3-8.

Figure 3-8 shows the detail B indicated in figure 3-7, view A. This represents the installation behind building 126, where the overhead line terminates. The last pole in the system is shown in the lower left corner. From the pole to the transformer bank, the underground conduit is indicated by dotted lines. The conduit runs underground to the concrete slab on which the transformers rest. Section A-A gives construction details of this slab.


GENERATOR PLANT
208/120 V 60 Hz
3 PH 4 WIRE
DISTRIBUTION
POINTS
208/120 V 1Ø
MOTOR POOL LIGHTS
AND 120 VOLT
SINGLE-PHASE MOTER
208/120 V 1Ø
LIVING
QUATERS
OPERATIONS
208 V
120 V 1Ø
208 V 3Ø
3-PHASE
MOTOR
208 V 3Ø
120 V 1Ø
TO MESS HALL

82.71

Figure 3-5.—3-phase/4-wire distribution system, pictorial view.



82.72

Figure 3-6.—3-phase/4-wire distribution system schematic.

The angle-iron symbols in figure 3-8, with the dimensions 3" x 3", indicate that the BUS (connecting conductor) running along the transformer primaries will be supported on posts made of 3" x 3" angles. From the transformer secondaries, underground conduits (indicated by dotted lines) will run to the junction box on building 126.

Pay attention to the various notes and details indicated in drawings. Your life, and the lives of your coworkers, may depend on the care you take when reading and interpreting drawings.

INTERIOR WIRING

Figure 3-9 shows an electrical layout superimposed on an outline taken from an architectural floor plan. The service line bringing power into the house is a three-wire line in 1 1/4-in. conduit. However, the fact that the line voltage is 120/240 indicates that these three wires must be two hot wires and a neutral wire from a four-wire system. The third hot wire is not brought into the house.

The service line feeds power by way of a service switch to a lighting panel, from which three BRANCH CIRCUITS run to the lighting fixtures and convenience outlets in the rooms. The symbols for these fixtures and outlets, and of the service switch and the lighting panel, are shown at the bottom of figure 3-9.

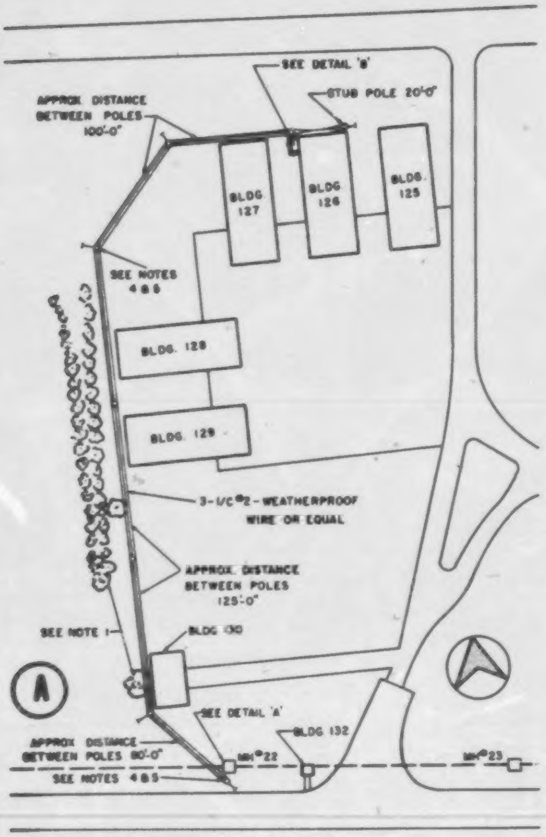
Figure 3-10 is a wiring diagram showing the connections for the layout shown in figure 3-9. After entering the building, the two hot wires (black) in the service lead are connected to and fused at the service switch, while the neutral wire bypasses the switch and runs to the NEUTRAL BAR in the panelboard, with a branch off to a waterpipe ground. Beyond the service switch, the two hot wires run to vertical LINE BARS in the panelboard.

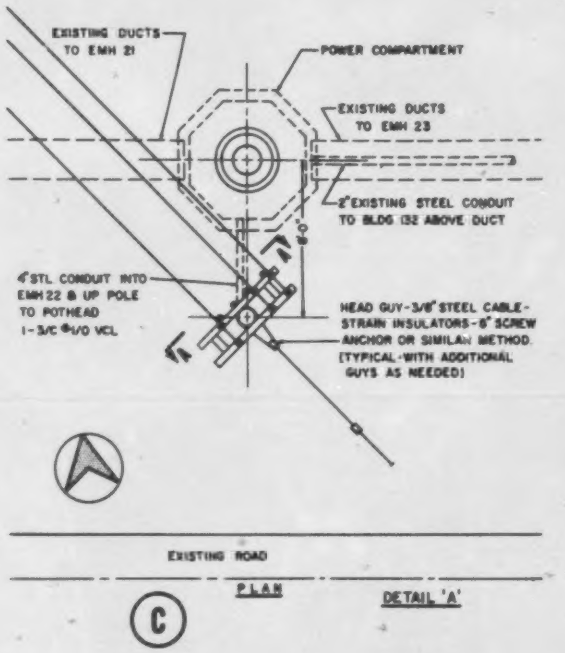
The panelboard is equipped to handle six circuits, with only three shown in the diagram. Consider branch circuit 4. It contains two wires, a hot wire running out from a circuit breaker in the panelboard, and a neutral (white) wire running back to the neutral bar in the panelboard. This circuit contains only a single switch, which turns all the lights in the circuit on or off simultaneously, but has no effect on the flow of power in circuits 2 and 6.

Circuit 2 similarly contains a hot wire out from the panelboard and a neutral wire back. Each of the lights in this circuit has its own switch, which controls the flow of power to that light only. Like circuit 6, circuit 2 has a hot wire out from the panelboard live bar, and a neutral wire back to the panelboard neutral bar.

WIRE COMMUNICATIONS

Schematics and wiring diagrams are used extensively in telephone communications. Figure


SEE DETAIL 'B'
STUB POLE 20'-0"
APPROX. DISTANCE BETWEEN POLES 100'-0"
BLDG. 127
BLDG. 126
BLDG. 125
SEE NOTES 4 & 5
BLDG. 128
BLDG. 129
3-1/C #2-WEATHERPROOF WIRE OR EQUAL
APPROX. DISTANCE BETWEEN POLES 125'-0"
SEE NOTE 1
BLDG 130
A
SEE DETAIL 'A'
BLDG 132
APPROX DISTANCE BETWEEN POLES 80'-0"
MH #22
MH #23
SEE NOTES 4 & 5


EXISTING DUCTS TO EMH 21
POWER COMPARTMENT
EXISTING DUCTS TO EMH 23
2" EXISTING STEEL CONDUIT TO BLDG 132 ABOVE DUCT
6'-0"
4" STL CONDUIT INTO EMH 22 & UP POLE TO POTHEAD 1-3/C #1/0 VCL
HEAD GUY-3/8" STEEL CABLE-STRAIN INSULATORS-8" SCREW ANCHOR OR SIMILAR METHOD. (TYPICAL-WITH ADDITIONAL GUYS AS NEEDED)
A
A
EXISTING ROAD
PLAN
DETAIL 'A'
C

GENERAL NOTES -

1 - TREES OBSTRUCTING POLE LINE TO BE TRIMMED OR REMOVED AS DIRECTED BY CONSTRUCTION OFFICER.

2 - PROVIDE LIGHTNING ARRESTERS, AT EACH END OF POLE LINE, ON ALL THREE OVERHEAD WIRES. GROUND LIGHTNING ARRESTERS WITH SUITABLE BARE WIRE CONNECTED TO DRIVEN GROUND ROD.

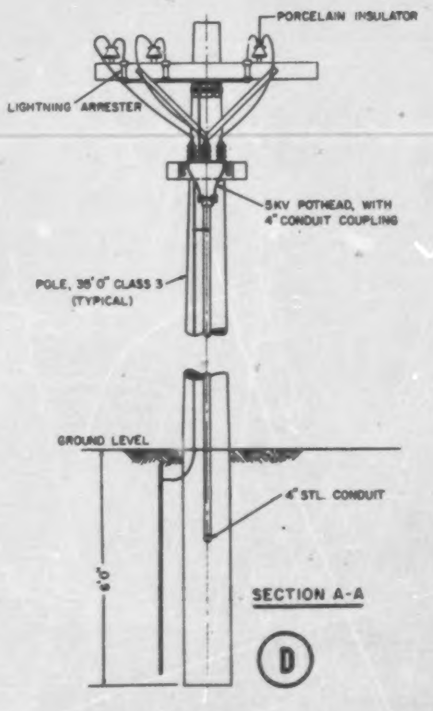
3 - INSULATORS TO BE PORCELAIN, PIN TYPE, INSULATOR PINS TO BE LOCUST WOOD OR EQUAL.

4 - TERMINAL POLES, AND POLES AT POINT OF CHANGE IN LINE DIRECTION, TO HAVE DOUBLE CROSS-ARMS; ALL OTHER POLES, SINGLE CROSS-ARM. CROSS-ARMS TO BE STANDARD 4 PIN, 5'-7" x 3 1/2" x 4 1/2", PIN SPACING 3'-0" ON CENTERS AND 14 1/2" ON SIDES.

5 - TERMINAL POLES TO HAVE ONE GUY; POLES AT POINT OF CHANGE IN LINE DIRECTION TO BE GUYED ACCORDING TO STANDARD PRACTICE. EACH GUY LINE TO HAVE TWO PORCELAIN STRAIN INSULATORS; THE LOCATION AND SPACING OF STRAIN INSULATORS AND GUY ANCHORS TO BE IN ACCORDANCE WITH STANDARD PRACTICE.

6 - MATERIAL AND WORKMANSHIP SHALL CONFORM TO ALL STANDARD CODES, REGULATIONS AND SPECIFICATIONS LISTED IN NAVFAC SPECIFICATIONS.

B


PORCELAIN INSULATOR
LIGHTNING ARRESTER
5KV POTHEAD, WITH 4" CONDUIT COUPLING
POLE, 35'-0" CLASS 3 (TYPICAL)
GROUND LEVEL
4" STL. CONDUIT
6'-0"
SECTION A-A
D

65.67

Figure 3-7.—Plot plan with electrical layout, general notes, detail and section drawings.

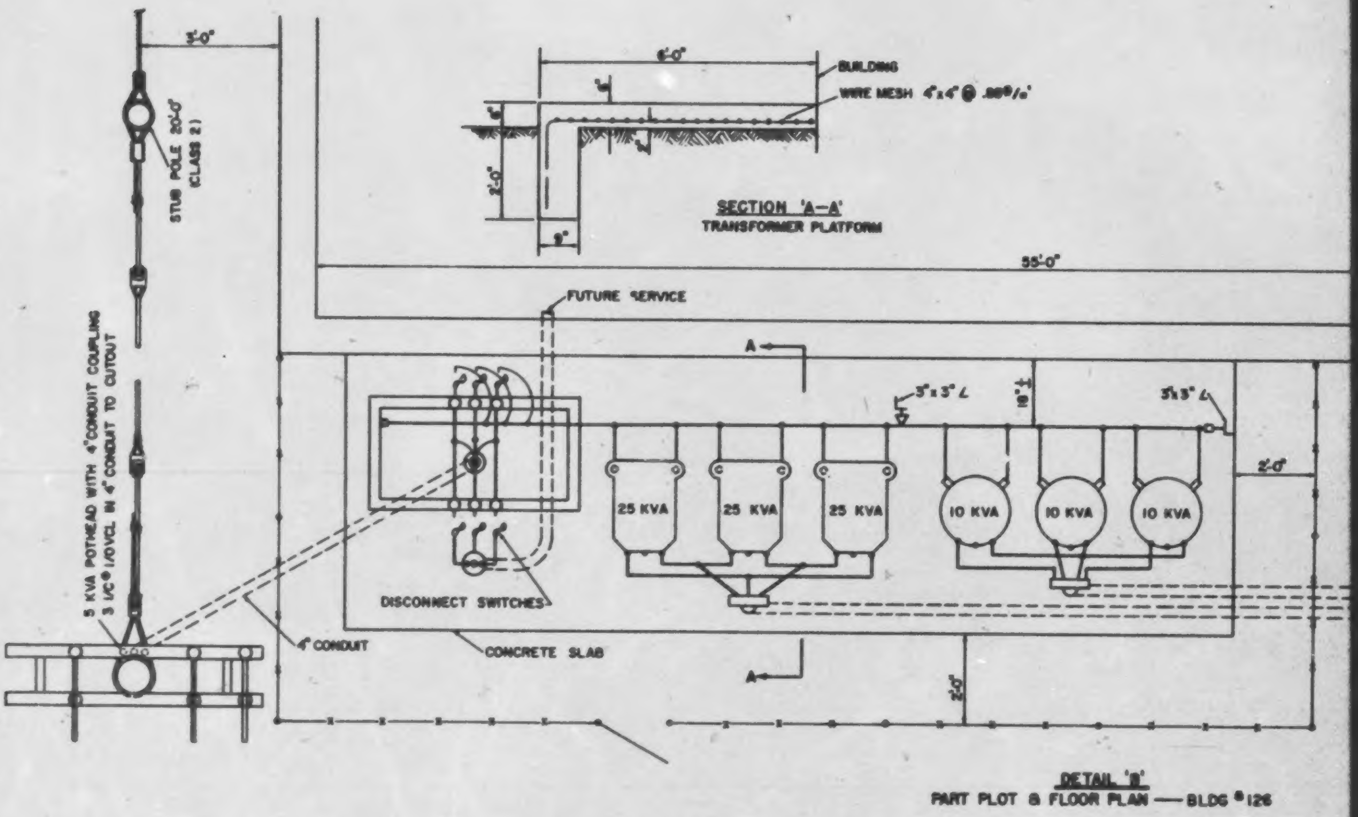

3'-0"
STUB POLE 20'-0" (CLASS 2)
5 KVA POTHEAD WITH 4" CONDUIT COUPLING
3 1/C# 1/0VCL IN 4" CONDUIT TO CUTOUT
6'-0"
BUILDING
WIRE MESH 4"x4" @ .08#/□'
6"
2'-0"
9"
SECTION 'A-A'
TRANSFORMER PLATFORM
55'-0"
FUTURE SERVICE
A
3"x3" ∠
18"
3"x3" ∠
2'-0"
25 KVA
25 KVA
25 KVA
10 KVA
10 KVA
10 KVA
DISCONNECT SWITCHES
4" CONDUIT
CONCRETE SLAB
A
2'-0"
DETAIL 'B'
PART PLOT & FLOOR PLAN — BLDG #126

Figure 3-8.—Detail B indicated in figure 3-7.

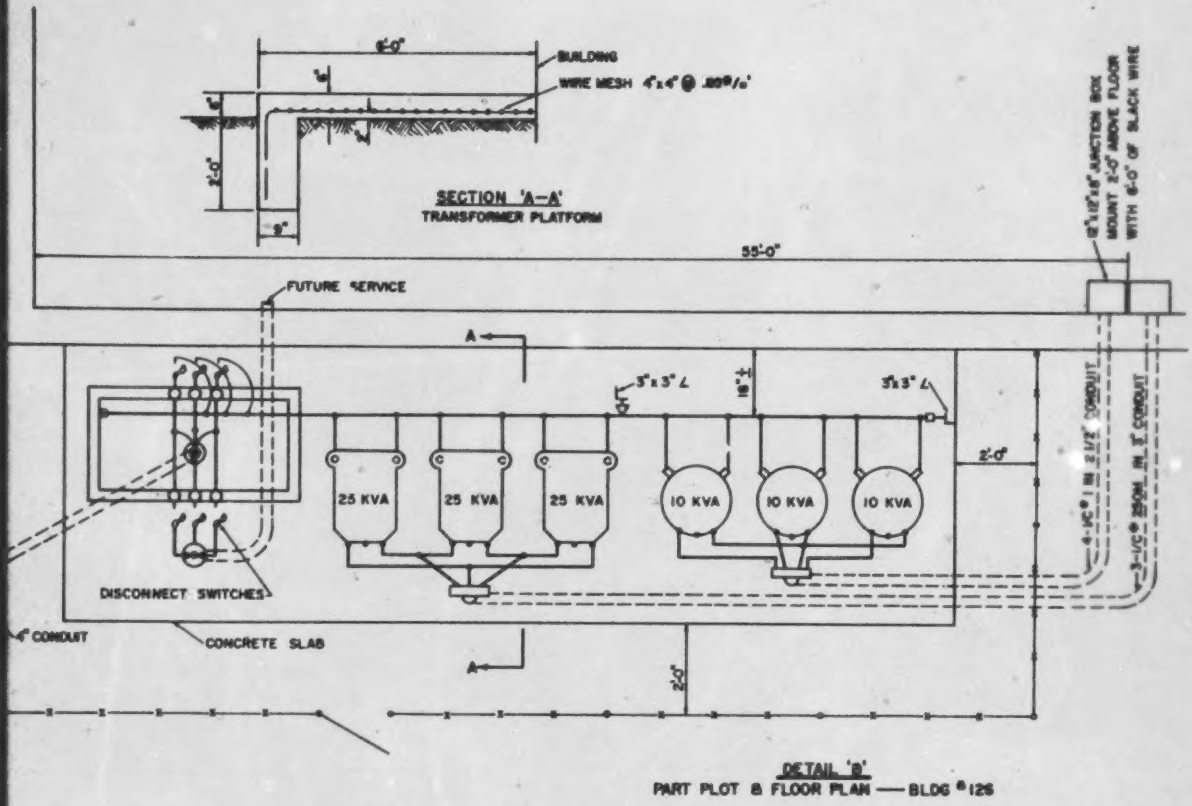
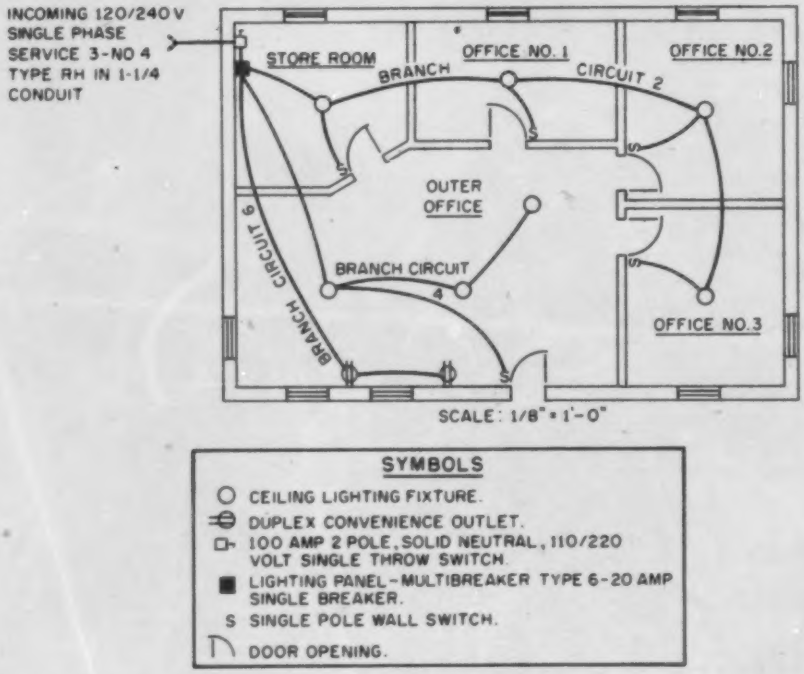
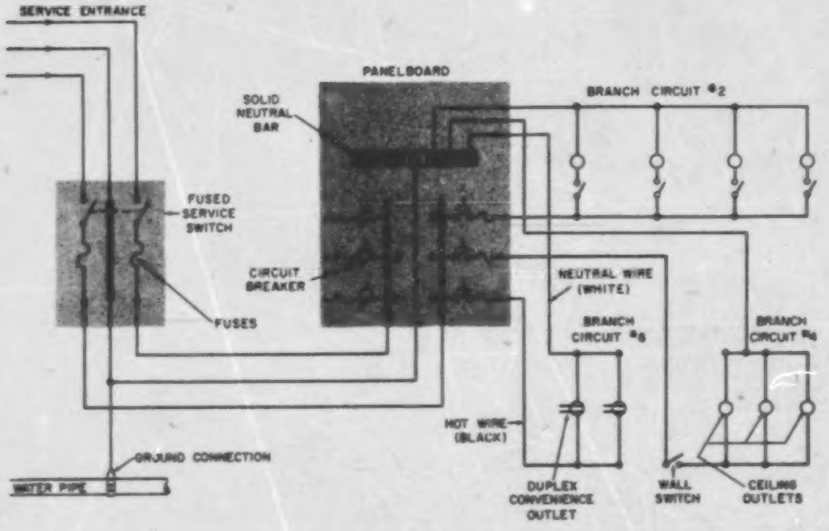

6'-0"
BUILDING
WIRE MESH 4"x4" @ .109#/□'
6"
6"
2'-0"
9"
SECTION 'A-A'
TRANSFORMER PLATFORM
55'-0"
12"x12"x8" JUNCTION BOX
MOUNT 2'-0" ABOVE FLOOR
WITH 6'-0" OF SLACK WIRE
FUTURE SERVICE
A
3"x 3" ∠
18"±
3"x3" ∠
2'-0"
25 KVA
25 KVA
25 KVA
10 KVA
10 KVA
10 KVA
4-1/C # 1 IN 2 1/2" CONDUIT
3-1/C # 250M IN 2" CONDUIT
DISCONNECT SWITCHES
4" CONDUIT
CONCRETE SLAB
A
2'-0"
DETAIL 'B'
PART PLOT & FLOOR PLAN — BLDG # 126

Figure 3-8.—Detail B indicated in figure 3-7. 65.69


INCOMING 120/240 V
SINGLE PHASE
SERVICE 3-NO 4
TYPE RH IN 1-1/4
CONDUIT
STORE ROOM
OFFICE NO. 1
OFFICE NO.2
BRANCH
CIRCUIT 2
S
OUTER
OFFICE
BRANCH CIRCUIT
4
BRANCH CIRCUIT 6
OFFICE NO.3
SCALE: 1/8" = 1'-0"
SYMBOLS
CEILING LIGHTING FIXTURE.
DUPLEX CONVENIENCE OUTLET.
100 AMP 2 POLE, SOLID NEUTRAL, 110/220 VOLT SINGLE THROW SWITCH.
LIGHTING PANEL-MULTIBREAKER TYPE 6-20 AMP SINGLE BREAKER.
S SINGLE POLE WALL SWITCH.
DOOR OPENING.

45.515

Figure 3-9.—Inside electrical layout.


SERVICE ENTRANCE
PANELBOARD
SOLID NEUTRAL BAR
BRANCH CIRCUIT #2
FUSED SERVICE SWITCH
CIRCUIT BREAKER
FUSES
NEUTRAL WIRE (WHITE)
BRANCH CIRCUIT #6
BRANCH CIRCUIT #4
HOT WIRE (BLACK)
GROUND CONNECTION
WATER PIPE
DUPLEX CONVENIENCE OUTLET
WALL SWITCH
CEILING OUTLETS

82.76

Figure 3-10.—Schematic for layout shown in figure 3-9.

3-11 shows a line circuit portion of a major switchboard circuit.

Section A shows the telephone set in its normal condition. The receiver is on the hook and all lamps and relays associated with this section are in their unoperated condition.

Section B delineates in bold lines what happens when a person at the calling station removes his receiver from the hook and the hookswitch contacts close. Battery, B1, sends current through the series circuit consisting of line relay LR1, the ring side of the line, the primary winding of induction coil P, the transmitter, and back to ground through the tip side of the line. Relay LR1 operates, closing the circuit of line lamp LL1, thus lighting the lamp.

As you can see from the above sequence of events, intelligent interpretation of schematics and diagrams will permit you to better understand and service telephone communication systems. Ask yourself when you encounter unfamiliar schematics, "What is the sequence of events? What relay energizes coil X or Y or Z? What is the normal current flow? What is supposed to happen?" As you ask and answer these questions, you will become more knowledgeable about circuit operations and functions.

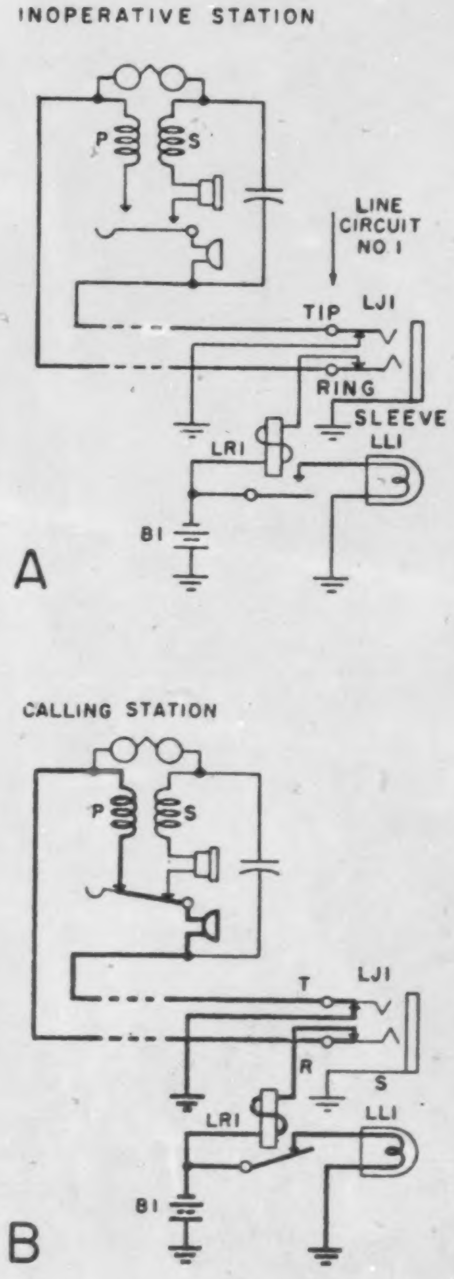
ELECTRIC APPLIANCE AND EQUIPMENT REPAIR

You may be required to install or repair the electric range or oven in the galley. How will you go about this task? Obviously, you will obtain the manufacturer's technical manual for the specific equipment you will be installing or repairing. Figure 3-12 shows a representative wiring diagram of one of these ranges.

What will you do if you are required to install range or oven timers? Figure 3-13 and 3-14 are wiring diagrams for range and oven connections to timers. Notice how use of these diagrams will enable you to install or repair the appliances indicated much more readily than blindly trying to trace out the circuitry for the appropriate connections.

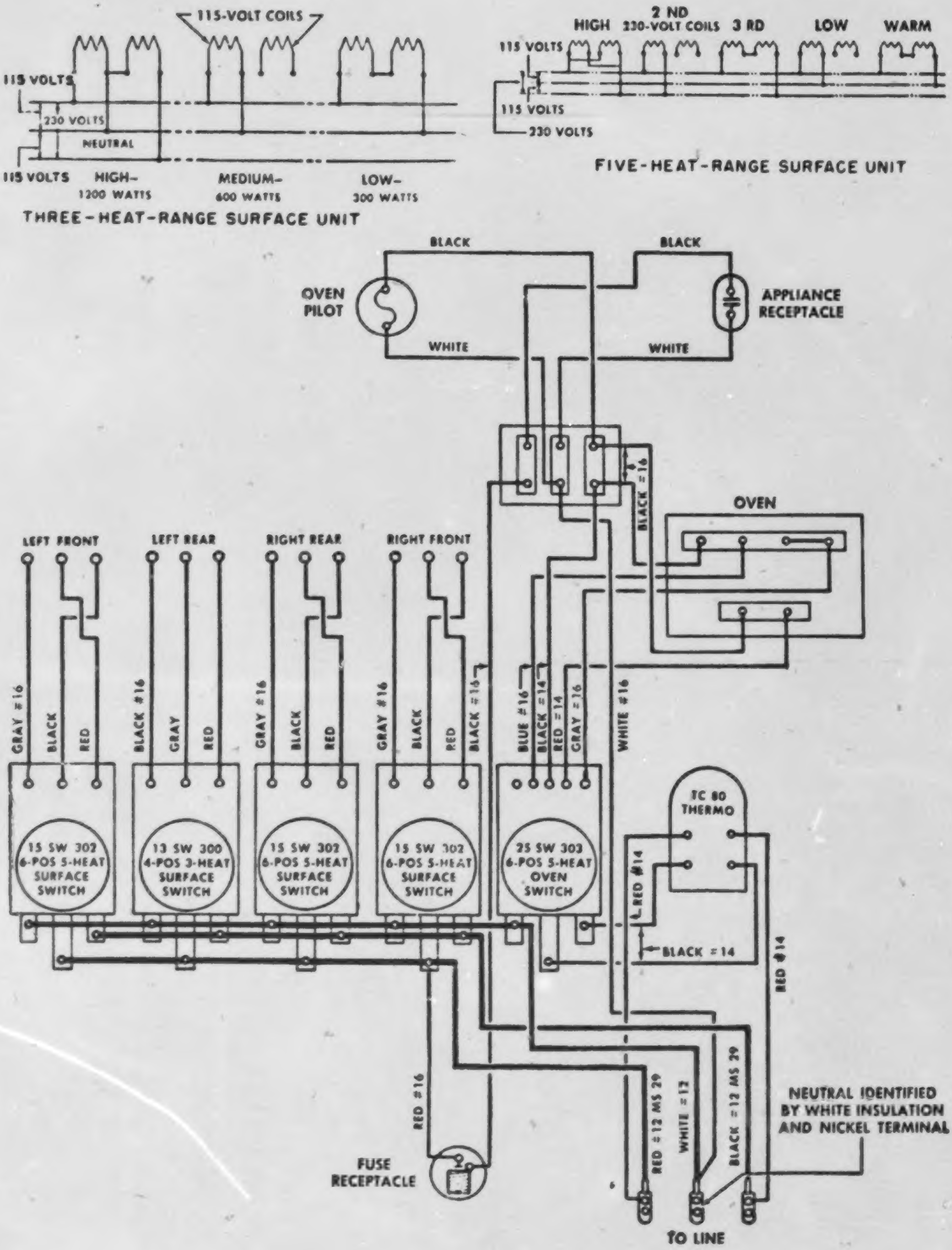
NAVAL FACILITIES ENGINEERING COMMAND DRAWINGS

The Construction Electrician very often works from a drawing prepared by the Naval



73.270

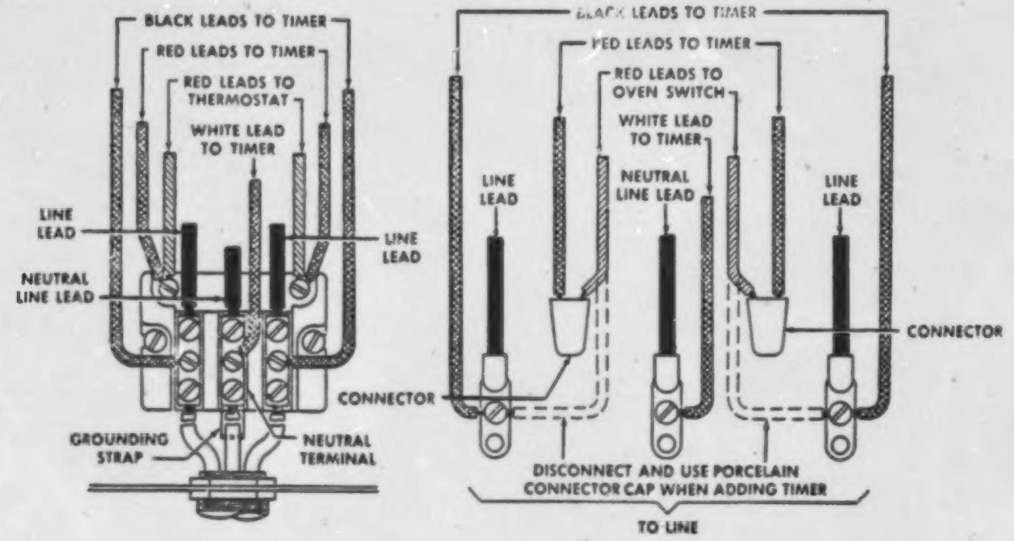
Figure 3-11.—Line circuit portion of switchboard.


THREE-HEAT-RANGE SURFACE UNIT

FIVE-HEAT-RANGE SURFACE UNIT

115-VOLT COILS
115 VOLTS
230 VOLTS
NEUTRAL
115 VOLTS
HIGH-
1200 WATTS
MEDIUM-
600 WATTS
LOW-
300 WATTS
HIGH
2 ND
230-VOLT COILS
3 RD
LOW
WARM
115 VOLTS
115 VOLTS
230 VOLTS
BLACK
BLACK
OVEN
PILOT
WHITE
WHITE
APPLIANCE
RECEPTACLE
BLACK #16
OVEN
LEFT FRONT
LEFT REAR
RIGHT REAR
RIGHT FRONT
GRAY #16
BLACK
RED
BLACK #16
GRAY
RED
GRAY #16
BLACK
RED
GRAY #16
BLACK
RED
BLACK #16
BLUE #16
BLACK #14
RED #14
GRAY #16
WHITE #16
15 SW 302
6-POS 5-HEAT
SURFACE
SWITCH
13 SW 300
4-POS 3-HEAT
SURFACE
SWITCH
15 SW 302
6-POS 5-HEAT
SURFACE
SWITCH
15 SW 302
6-POS 5-HEAT
SURFACE
SWITCH
25 SW 303
6-POS 5-HEAT
OVEN
SWITCH
TC 80
THERMO
RED #14
BLACK #14
RED #14
RED #16
RED #12 MS 29
WHITE #12
BLACK #12 MS 29
NEUTRAL IDENTIFIED
BY WHITE INSULATION
AND NICKEL TERMINAL
FUSE
RECEPTACLE
TO LINE
73.271

Figure 3-12.—Range wiring diagrams.


BLACK LEADS TO TIMER
RED LEADS TO TIMER
RED LEADS TO THERMOSTAT
WHITE LEAD TO TIMER
LINE LEAD
NEUTRAL LINE LEAD
LINE LEAD
CONNECTOR
GROUNDING STRAP
NEUTRAL TERMINAL
BLACK LEADS TO TIMER
RED LEADS TO TIMER
RED LEADS TO OVEN SWITCH
WHITE LEAD TO TIMER
LINE LEAD
NEUTRAL LINE LEAD
LINE LEAD
CONNECTOR
DISCONNECT AND USE PORCELAIN CONNECTOR CAP WHEN ADDING TIMER
TO LINE

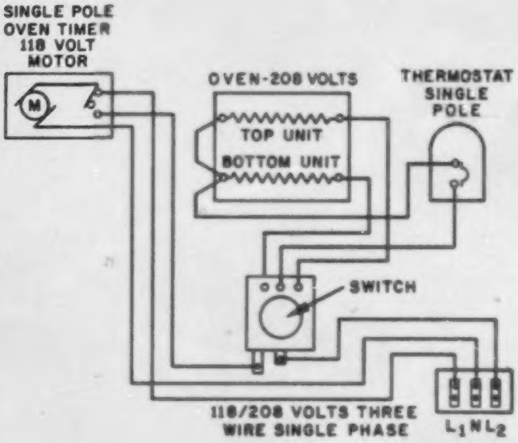
73.272

Figure 3-13.—Representative wiring diagrams for range timer connections.

Facilities Engineering Command. Construction battalions seldom have the time or facilities for preparing a set of blueprints. For this reason, NAVFAC has prepared a series of drawings for use at advanced bases. This series of drawings is entitled Facilities Planning Guide, Volume I, NAVFAC P-437, and is kept in the operations or engineering office. These drawings cover most types of major installations. Copies are made available to all battalions before they leave the United States.

A complete set of drawings is usually composed of a number of separate drawings. The specific information which the drawings provide on proper installation of equipment and operating procedures will furnish satisfactory answers to many installation problems.

The standard drawings prepared by NAVFAC can save a surprising amount of time in the erection of a number of similar structures, and in wiring them for heating and lighting. For example, if a series of quonsets are to be erected, use of a standard plan enables the man in charge to put the various tasks on an assembly line basis, and makes it possible to erect an entire quonset town in less time than it would take to build an ordinary house.


SINGLE POLE OVEN TIMER 118 VOLT MOTOR
M
OVEN-208 VOLTS
TOP UNIT
BOTTOM UNIT
THERMOSTAT SINGLE POLE
SWITCH
118/208 VOLTS THREE WIRE SINGLE PHASE
L1 N L2

73.273

Figure 3-14.—Representative diagram of electric range single-pole oven timer.

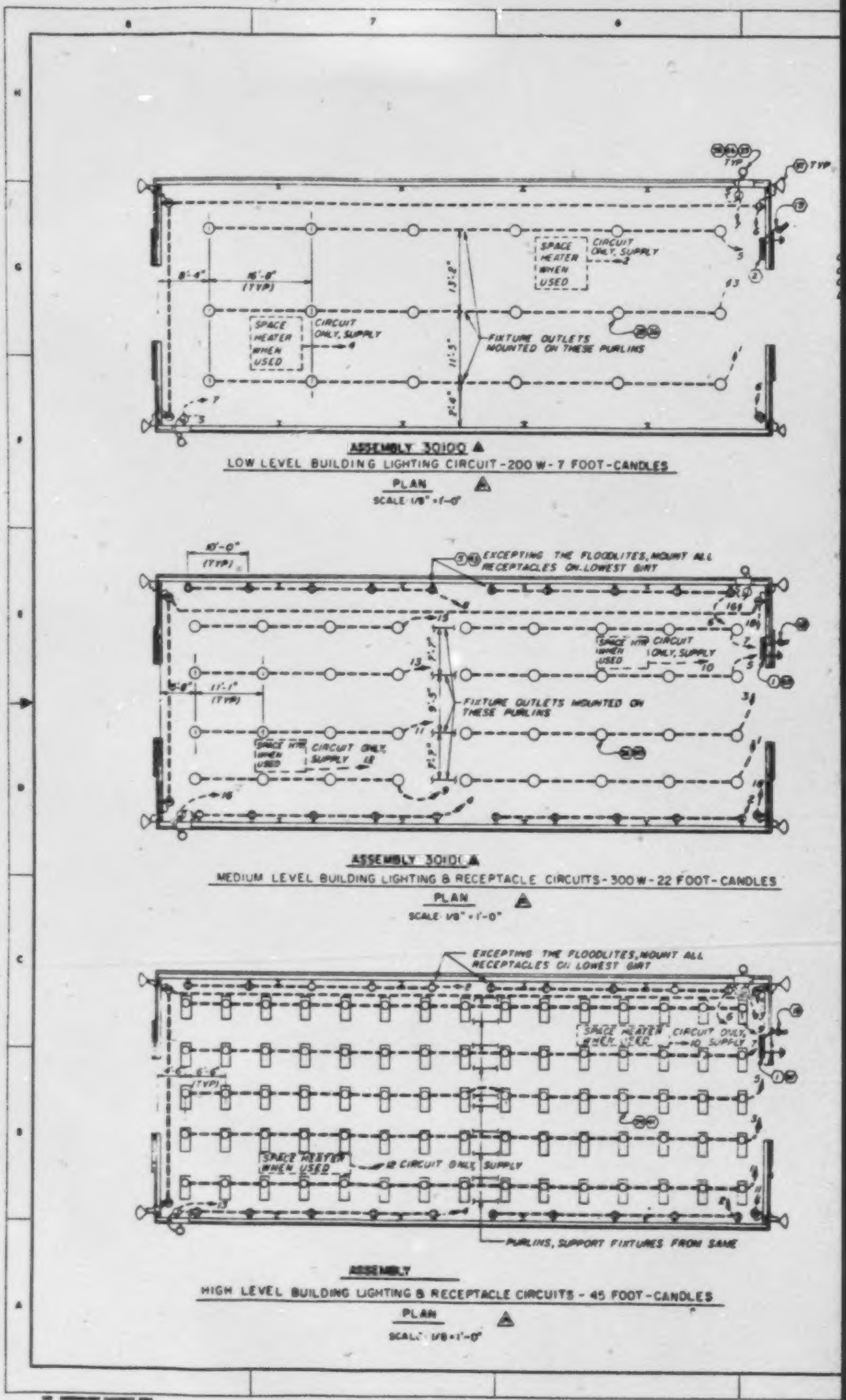
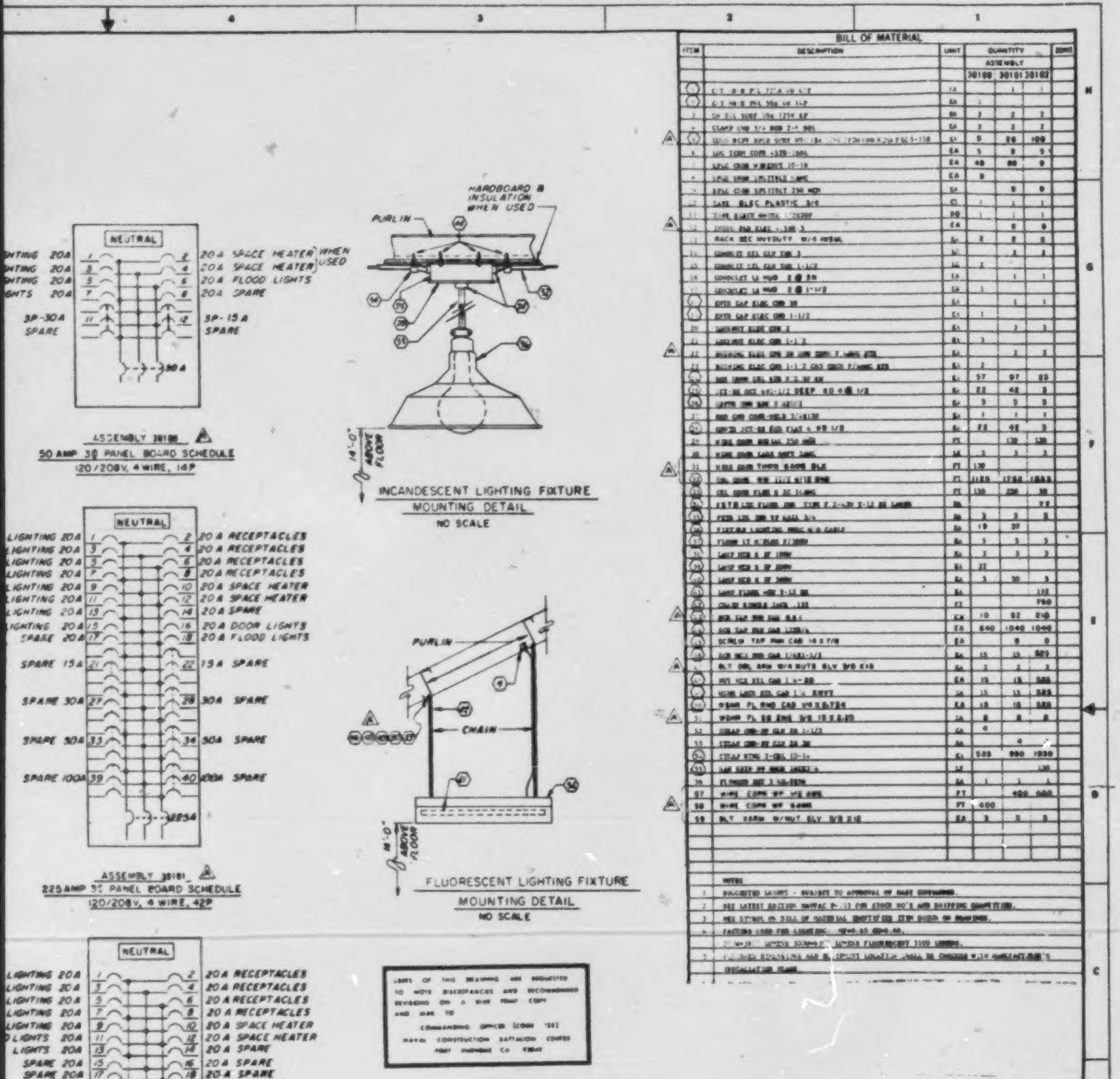

8
7
6
H
G
F
E
D
C
B
A
TYP
TYP
8'-4"
16'-8"
(TYP)
13'-2"
11'-5"
2'-6"
SPACE HEATER WHEN USED
CIRCUIT ONLY, SUPPLY 2
CIRCUIT ONLY, SUPPLY 4
FIXTURE OUTLETS MOUNTED ON THESE PURLINS
ASSEMBLY 30100
LOW LEVEL BUILDING LIGHTING CIRCUIT-200 W-7 FOOT-CANDLES
PLAN
SCALE 1/8" = 1'-0"
10'-0"
(TYP)
EXCEPTING THE FLOODLITES, MOUNT ALL RECEPTACLES ON LOWEST GIRT
11'-1"
(TYP)
SPACE HTR WHEN USED
CIRCUIT ONLY, SUPPLY 10
CIRCUIT ONLY, SUPPLY 18
FIXTURE OUTLETS MOUNTED ON THESE PURLINS
ASSEMBLY 30101
MEDIUM LEVEL BUILDING LIGHTING & RECEPTACLE CIRCUITS-300 W-22 FOOT-CANDLES
PLAN
SCALE 1/8" = 1'-0"
EXCEPTING THE FLOODLITES, MOUNT ALL RECEPTACLES ON LOWEST GIRT
6'-6"
(TYP)
SPACE HEATER WHEN USED
CIRCUIT ONLY, SUPPLY 10
12 CIRCUIT ONLY SUPPLY
PURLINS, SUPPORT FIXTURES FROM SAME
ASSEMBLY
HIGH LEVEL BUILDING LIGHTING & RECEPTACLE CIRCUITS - 45 FOOT-CANDLES
PLAN
SCALE 1/8 = 1'-0"

Figure 3-15.—40' x 100'


BILL OF MATERIAL
ASSEMBLY 38100
50 AMP 3Ø PANEL BOARD SCHEDULE
120/208V, 4 WIRE, 14P
ASSEMBLY 38101
225 AMP 3Ø PANEL BOARD SCHEDULE
120/208V, 4 WIRE, 42P
ASSEMBLY 38102
225 AMP 1Ø PANEL BOARD SCHEDULE
120/208V, 4 WIRE 42P
NEUTRAL
HARDBOARD & INSULATION WHEN USED
PURLIN
INCANDESCENT LIGHTING FIXTURE MOUNTING DETAIL
NO SCALE
CHAIN
FLUORESCENT LIGHTING FIXTURE MOUNTING DETAIL
NO SCALE
GRAPHIC SCALE
THIS DWG SUPERSEDES DWG NO'S 1028204, 1028205, 1028206. DATED 4-22-65 AND 1028323 DATED 11-4-65
BLDG 40'X 100' 889708
REFERENCE DWGS
REV. B/M & BODY OF DWG
REVISION DESCRIPTION
DEPARTMENT OF THE NAVY
NAVAL FACILITIES ENGINEERING COMMAND
SEABEE SYSTEMS ENGINEERING OFFICE
U.S. NAVAL CONSTRUCTION BATTALION CENTER
PORT HUENEME, CALIFORNIA
ADVANCED BASE FUNCTIONAL COMPONENT
40'X 100' RIGID FRAME BUILDING
LIGHTING, RECEPTACLE & SERVICE
ENTRANCE ASSEMBLIES
ELECTRICAL STANDARDS
CODE IDENT NO 80091
COMPONENT-ASSEMBLY 38100, 38101, 38102
NAVFAC DRAWING NO. 1109858
SCALE AS NOTED
SKETCH NO. 89035
SHEET 1 OF 1

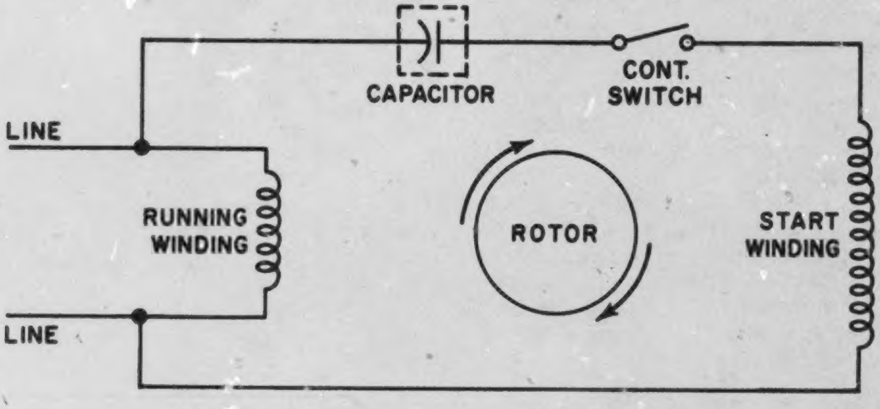
73,367

igid frame building assemblies.

However, a single master plan cannot be used for all buildings. Changes are often necessary because of the use of the building and the type of machinery to be installed. Where shops are being erected, there will probably be at least one standard drawing for each type of shop.

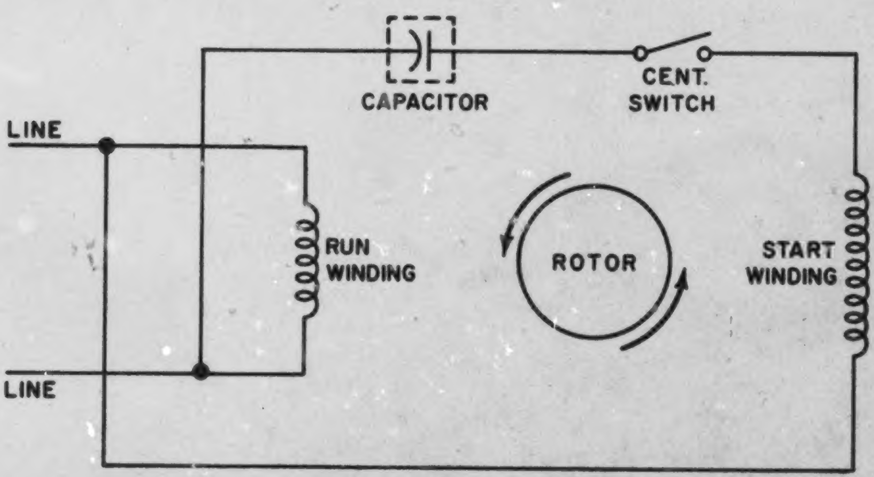
Figure 3-15 is a standard drawing for a 40' x 100' rigid frame building being used for three different types of assemblies. All three assembly drawings show where the main panel is located, its size, the material needed to mount it, the number and types of lighting fixtures, the number of receptacles used, and any special details in its construction.

In studying the print, notice that each home run (return to panel circuit breaker) is given a number. This number indicates what circuit breaker this circuit will tie into in the main panel. The panel is numbered and each


CAPACITOR
CONT. SWITCH
LINE
RUNNING WINDING
ROTOR
START WINDING
LINE

73,368

Figure 3-16.—Freehand sketch of a single-phase capacitor start motor connected for clockwise rotation.


CAPACITOR
CENT. SWITCH
LINE
RUN WINDING
ROTOR
START WINDING
LINE

73,369

Figure 3-17.—Freehand sketch of a single-phase capacitor start motor connected for counter-clockwise rotation.

circuit identified for general use and tie-in purposes.

The mounting details shown on the drawing for the incandescent lighting fixture are the mounting height above the floor (14' 0") and the type of mounting used. For instance, number 25 (inside the hex symbol for the incandescent fixture) refers you to number 25 on the bill of material. The bill of material describes item number 25 as a junction box, octagon, 4" x 1 1/2" deep, with 4 knockout plugs for 1/2 inch connectors. Assembly 30100 will need 22 of these, 30101 will need 42, and 30102 will need three. Assembly 30102 will use fluorescent lighting, suspended by a chain 14' 0" above the floor. Like the example (number 25), all hardware used is indicated by numbers, which refer you to the bill of material for descriptions and amount.

The bill of material lists all items by number, description, unit and quantity for each assembly. The notes on the bottom of this bill give special instructions that will be useful when working on the job. For example, note 5 states: "Finished dimensions and equipment location shall be checked with manufacturer's installation plans." This could call for extra or special materials to install a special piece of equipment. You should be aware of this, because when changes are necessary, the deletion or addition should be shown on the appropriate print to keep them AS BUILT.

From studying prints of these assemblies and with a good knowledge of interior wiring, you should be able to wire up all three of these assemblies with the least amount of trouble and in the shortest time.

FREEHAND SKETCHES

Being able to redraw a circuit can be very helpful and necessary at times. An example of this could be changing the direction of rotation of a single-phase, capacitor-start motor which runs clockwise. You would want to reconstruct the circuit by drawing the running and starting coils according to the existing hookup. Then you would redraw the hookup the way it should be for the motor to run counterclockwise. (See figs. 3-16 and 3-17.)

CHAPTER 4

SPECIAL TOOLS

As a Construction Electrician, you must be able to use the special tools and equipment needed in your work. Among these are the portable power tools, such as drills and grinders, the pneumatic pavement breaker, power hacksaws, powder-actuated tools, air compressors, and earth augers.

BATTALION TABLE OF ALLOWANCE

In an NMCB, your portable tools will come from prepackaged kits which are part of the equipment allotted to a construction battalion for overseas deployment. The battalion's table of allowance (TOA) takes into consideration a manning level of 24 officers and 738 enlisted personnel in a wartime deployment and a northern temperate environment. Four men can work out of each prepackaged kit of tools. Part I of the TOA lists the battalion organic equipment and material. (See figure 4-1.) Part II consists of equipment and supplies controlled by COMCBLANT/COMCBPAC. The tools used by "B" company shops and field crews come under Part I, section 6.

The contents of an electrician's tool kit are listed in figure 4-2, those of a lineman's kit in figure 4-3. Notice that the kits contain only basic handtools. (Power tools have to be checked out from the central toolroom.) The kits for a battalion's shops and maintenance platoon include plumber's kits, refrigeration kits, sheet metal kits, an electric arc welding kit, and miscellaneous equipment (fig. 4-4). As a crew leader or shops supervisor, you will be responsible for the checkout, control and inventory, and care and maintenance of these kits. COMCBPAC/COMBLANT Instruction 10290.2E covers the procurement, issue, and care of handtools and power tools; tool custody record cards; power tool preventive maintenance; and the drawing of sample tool kit boxes.

PORTABLE POWER TOOLS

In the shop or field, you will be using portable power drills, hammers, and grinders. You should be thoroughly familiar with the operation and care of these tools and with all applicable safety precautions. Only the portable power tools not covered in *Tools and Their Uses*, NAVPERS 10085-B, are discussed in this chapter.

Part I

(1) Personnel
(2) Weapons and Infantry Equipment
(3) NBC Warfare, Radiac, Damage Control, and Safety Equipment
(4) Administrative and General Services
(5) Maintenance Tools and Shop Equipment
(6) Construction Tools and Kits
(7) Construction Oriented Consumables
(8) Mount-out Material and Containers
(9) Clothing and Bedding
(10) Medical and Dental
(11) Communication and Test Equipment
(12) Forms and Publications

Part II

(20) Civil Engineering Support Equipment (CESE)
(21) Facilities
(22) Collateral Equipment for Facilities
(23) Petroleum-Oil-Lubricants (POL)
(24) Provisions
(25) Repair Parts
(26) Tactical Support Facilities
(27) Contingency Support

Figure 4-1.—Battalion Table of Allowance.

SOLDER 50/50 ROSIN 3/32	1 LB
SOLDERING GUN ELECTRIC	1 EA
STRIPPER CABLE F/TYPE NM	4 EA
BRACE BIT RATCHET 12	1 EA
PLIERS DIAGONL CUT 7 1/2	4 EA
FILE AMPAT RD BAST 10	1 EA
KNIFE POCKET W/SCDR-SCRPR	4 EA
FILE AMPAT REG TPR 7	1 EA
STRIPPER WIRE ELECTRIC 10/18 AWG	4 EA
BLADE HACKSAW 18T 12LG	2 BD
BLADE HACKSAW 32T 12LG	2 BD
FRAME HACKSAW ADJ 10-12	2 EA
SAWS NEST KEY-COMPS-NAIL	1 SE
HOLDER FILE TOOL ADJ JAWS	2 EA
CHISEL SET BUTT WOOD W/RL	1 SE
PLIERS SLIP JOINT 11-1/4 LG SMOOTH JAWS	4 EA
SCREWDRIVER OFFSET 1/4N 5 1/4N OA	2 EA
AWL SCRATCH 3 1-2	4 EA
SCREWDRIVER COMM 1/4X4N	4 EA
PULLER FUSE 0-100 AMP	1 EA
SCREWDRIVER CABINT 3/16X6	4 EA
SCREWDRIVER FLAT TIP MGNTIC 1/8X2N	4 EA
SCREWDRIVER PHILIP NO 3 TIP 6N BLADE	4 EA
SCREWDRIVER PHILIP NO 2 TIP 4N BLADE	4 EA
PLIERS LINEMAN 8N	4 EA
WRENCH OE ADJ 8N	4 EA
PULLER FUSE 100-600 AMP	1 EA
PLIERS LONG NOSE 6N	4 EA
SCREWDRIVER CABINT 3/16X8 3/16X8N	4 EA
WRENCH OE ADJ 12N	2 EA
WRENCH PIPE 10N	2 EA
WRENCH V-GRIP PLIER 8 1/2	4 EA
SCREWDRIVER START 1/4X6	4 EA
SCREWDRIVER FLAT TIP 3/8X8N	4 EA
SCREWDRIVER FLAT TIP 5/16X6N	4 EA
PUNCH CENTER 3/8X4	1 EA
PUNCH CENTER 1/4X3 1/4 NO 2	1 EA
HAMMER HAND OUTLET BOX	4 EA
WRENCH SET SOCKT SPINNER	2 SE
SCREWDRIVER STUB FLAT TIP 1/4X1 3/4N	4 EA
KEY SET SCKT HEAD SCREW	1 SE
DRILL ELEC PORT 1/2	1 EA
DRILL SET TWIST 1/16 TO 1/2 BY 16THS	1 SE
BIT SET AUGER 1/4 TO 1 N	1 SE
TOOL BOX STL MECHANIC	4 EA
POCKET ELEC TOOL	4 EA
TAPE MEASURE FLEX 10FT	4 EA
RULE WOOD FLDG H-DTY 72N	4 EA
LEVEL AND PLUMB 9N	1 EA
INDICATOR LINE VOLTAGE	4 EA

Figure 4-2.— Electrician's tool kit list for four men (80006).

BLOCK AND TACKLE 1/2 F-RP	2 EA
BAG LINEMAN GLOVE	4 EA
CLIMBERS TREE-POLE WITH STRAPS AND PADS	4 SE
CLIMBER STRAP AND PAD SET	4 SE
STRAP SFTY NYLON 1-3/4X84	4 EA
BELT TOOL LINEMAN SZ 36	1 EA
BELT TOOL LINEMAN SZ 38	2 EA
BELT TOOL LINEMAN SZ 40	1 EA
FILE AMPAT FLT SMTH 12	2 EA
BRACE BIT RATCHET 12	1 EA
CHISEL COLD 3/4	2 EA
FILE AMPAT MILL BAST 12	2 EA
KNIFE LINEMANS FLDNG 3	4 EA
BLADE HACKSAW 18T 12LG	1 BD
BLADE HACKSAW 24T 12LG	1 BD
FRAME HACKSAW ADJ 10-12	2 EA
HOLDER FILE TOOL ADJ JAWS	2 EA
CHISEL FIRMER 2N	2 EA
CHISEL SET BUTT WOOD W/RL	2 SE
HAMMER HAND ENG 2 1/2 LB	2 EA
SCREWDRIVER FLAT TIP 3/8X12N	4 EA
PLIERS LINEMAN 8N	4 EA
WRENCH OE ADJ 8N	4 EA
WRENCH OE ADJ 12N	4 EA
WRENCH LINEMAN DBL	4 EA
PLIERS SLIP JOINT 10N	4 EA
SCREWDRIVER FLAT TIP 3/8X8N	4 EA
SCREWDRIVER FLAT TIP 5/16X6N	4 EA
HAMMER HAND CARP 20 OZ RIPPING FBR GLS HNDL	2 EA
BIT AUGER SHIP 11/16X29	2 EA
BIT AUGER SINGLE SPUR CAR W/SCREW POINT 9/16X18N	2 EA
BIT AUGER SINGLE SPUR CAR W/SCREW POINT 7/16X18N	2 EA
BIT AUGER SINGLE SPUR CAR W/SCREW POINT 11/16X18N	2 EA
BIT AUGER SINGLE SPUR CAR W/SCREW POINT 13/16X18N	2 EA
BAG TOOL SATCHEL CANVAS 24X14X6N	4 EA
BAG BOLT NUT W/BELT LOOP	1 EA
RULE WOOD FLDG H-DTY 72N	4 EA
TAPE MEASURE CHROME 100FT GENERAL PURPOSE	1 EA
TAPE ELEC PLASTIC 3/4	2 RO
HOOK PULLING STRANDVISES	2 EA
PROTECTOR RUBR GLV	4 PR
GLOVE ELEC RUBBER SZ 10	2 PR
GLOVE ELEC SZ 11	2 PR
GLOVE LINEMANS LTHR	4 PR

Figure 4-3.—Lineman's tool kit list for four men (80007).

GRINDING MACH BNCH 1X7WHL	2 EA
TORCH OUTFIT CUTNG-WLDNG	4 EA
BENDER PP-COND HY 1 1/2-4	1 EA
THREADING MACH PIPE-BOLT PORT 1/8-2PP 1/4-1 BOLT	2 EA
BLADE HOLE SAW 2N	1 EA
BLADE HOLE SAW 3/4N	1 EA
BLADE HOLE SAW 7/8N	1 EA
BLADE HOLE SAW 1N	1 EA
BLADE HOLE SAW 1 1/8N	1 EA
BLADE HOLE SAW 1 1/4N	1 EA
BLADE HOLE SAW 1 3/8N	1 EA
BLADE HOLE SAW 1 1/2N	1 EA
BLADE HOLE SAW 1 5/8N	1 EA
BLADE HOLE SAW 1 3/4N	1 EA
BLADE HOLE SAW 1 7/8N	1 EA
ARBOR HOLE SAW NO 1 5/8X1 1/8N	1 EA
ARBOR HOLE SAW NO 2 1 1/4X4 1/2N	1 EA
ARBOR HOLE SAW NO 3 1 1/4X4 1/2N	1 EA
GRINDER ATTACH DRILL TWST	1 EA
TRUCK HAND LIFT PALLET TYPE 4000 CAP HYD	1 EA
TRUCK HAND 2 WHL 500 CAP	1 EA
TAIL LINE ASSY SFTY BELT	12 EA
BELT TOOL LINEMAN SZ-42	20 EA
COMPRESSOR 15CFM 175 PSI SHOP EMD 208V 60HZ 3 PH	2 EA
HOSE ASSY KIT AIR COMP 15-40CFM SHOP	2 EA
OVEN WELD ELCTRD STORAGE	2 EA
SPRAY PAINT OUTFIT W/COMP	1 EA
CUTTER TPR JNT ASB CEM PIPE PRESSURE 3-6 INCH	1 EA
SAW MITRE BOX 11PT 26	4 EA
MITER BOX W/O SAW	4 EA
PUNCH-DIE SET KNOCKOUT 2-2 1/2IPS F/1 15/16-2 3/8N HOLE SIZE	4 SE
PUNCH-DIE SET KNOCKOUT 1/2-1 1/4IPS F/7/8-1 11/16N HOLE SIZE	4 SE
CUTTER TPR JNT ASB CEM PIPE NON-PRESSURE 3-6 INCH	1 EA
PUNCH-DIE KNOCKOUT 2 1/2IPS F/2 7/8N HOLE SIZE	3 EA
PUNCH-DIE KNOCKOUT 3 1/2IPS F/4N HOLE SIZE	2 EA
PUNCH-DIE KNOCKOUT 3N IPS F/3 1/2N HOLE SIZE	3 EA
STICK CLAMP HOT LINE	2 EA
TAPE FISH POLYETHYLENE 50FT W/REEL	3 EA

TAPE FISH POLYETHYLENE 100 FT	3 EA
FLATTER 2 1/2X5 BLKSMITH	1 EA
SHOVEL RD PT LG HNDL	10 EA
VISE SHT MTLWKR 9	2 EA
VISE WOODWORKERS 12	4 EA
STAKE SHT MTL BLOWHORN	2 EA
VISE BENCH 4 1/2N JAWCOMB	2 EA
PIKE POLE 14FT LG	8 EA
BENDER CONDUIT 1-1 1/4	6 EA
SHOVEL SQ PT D HNDL	4 EA
PLATE BENCH MTLWKR	2 EA
HAMMER HAND BLKSMTH 3LB CROSS PIEN	2 EA
BENDER CONDUIT 1/2-3/4	8 EA
DRESSER WHL ABR W/X CTRS	2 EA
JACK REEL HAND	4 EA
HAMMER HAND BLKSMTH SET	1 EA
TAPE FISH 1/8X100	2 EA
ANVIL BLACKSMITH 200LB	1 EA
STICK HOT LINE	2 EA
SHOVEL SQ PT LG HNDL	15 EA
HANDLING TOOL SHT MTL VACUUM CUPS	2 EA
STAKE SHT MTL CANDLE MOLD	2 EA
BENDER EMT 1N	5 EA
BENDER EMT 1/2N	6 EA
BENDER EMT 3/4N	6 EA
DRESSER WHL ABR ROTARY	2 EA
ATTACHMENT SET SPEED REDC	4 EA
SHEAR MTL CUTNG ELEC PORT	2 EA
SHEAR MTL ELEC 16GA	2 EA
ETCHER ELEC PORT VIBRATOR	1 EA
TOOL BOX 18X10X13N MECH	3 EA
CHEST SHT MTL WKR STL	2 EA
STEPLADDER FIBERGLASS 12F F/ELECTRICIANS USE	1 EA
STEPLADDER FIBERGLASS 8F F/ELECTRICIANS USE	1 EA
STEPLADDER FIBERGLASS 6F F/ELECTRICIANS USE	1 EA
LADDER EXTENSN 30F	2 EA
STEPLADDER ALUM ALLOY 6FT	5 EA
STEPLADDER ALUM ALLOY 8FT	5 EA
STEPLADDER ALUM ALLOY 12F	1 EA
INSULATOR HOSE ELEC	4 EA
INSULATOR HOOD ELEC	4 EA
BLANKET LINEMAN	4 EA
TESTER PORT ELEC TOOL MULTI-AMP B2500	1 EA
SCALE BEAM INDICAT 1200LB	1 EA
METER AIR VELOCITY 0-1000 FPM	1 EA

Figure 4-4.—Miscellaneous "B" company equipment (83002).

The portable power tools that you use may be powered by electric motors or by air (pneumatic) motors. Whether electric-powered or air-powered, the tools are essentially the same and the procedures for using them are the same. The following paragraphs concern the pneumatic drill and pneumatic grinder, probably the most widely used portable air-powered tools. As an Electrician, you will be required to maintain the portable pneumatic tools as well as use them.

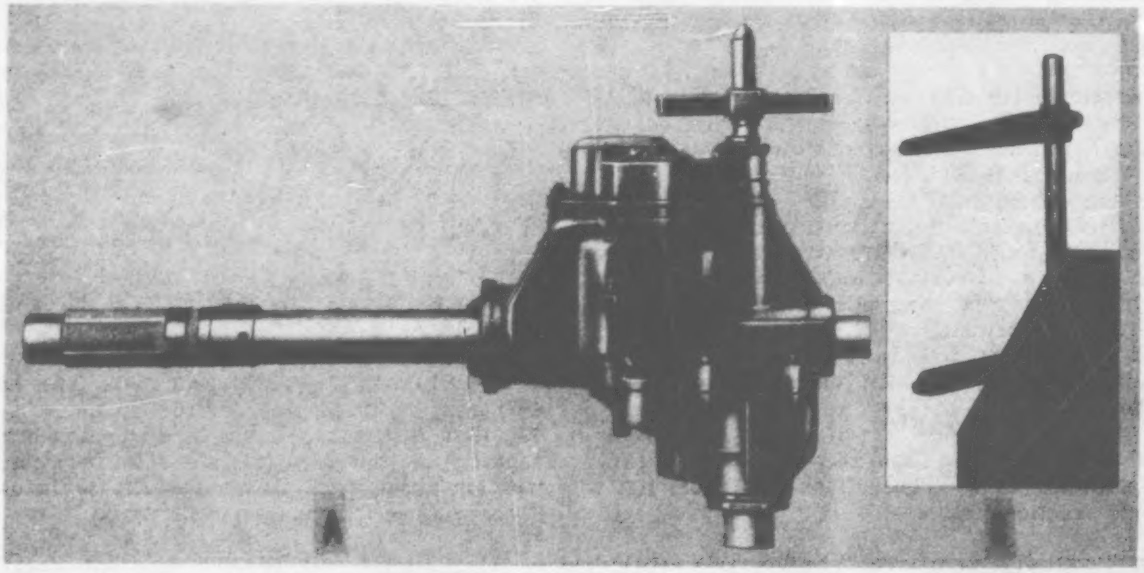
PNEUMATIC DRILL

The heavy-duty pneumatic drill, shown in view A of figure 4-5, is reversible. Its speed can be closely controlled by means of the throttle valve located in the handle. The variable speed feature of this drill makes it particularly useful for heavy-duty drilling in places that are hard to reach.

Another feature of this drill is that it has a feed screw which can be used in conjunction with a special type of drill stand called OLD MAN. This drill stand is shown in part B of figure 4-5. When you drill a hole using the pneumatic drill with the OLD MAN, make sure you wear goggles during the drilling operation. Before connecting the airhose to the drill, blow out any foreign matter that may be in the hose. Next connect the hose and drill, and turn on the air at the compressed air outlet. Then turn on the drill and test run it. In drilling, first place the twist drill in the socket. Then adjust the feed screw in the machine to its lowest position and place the point of the feed screw in one of the indentations in the arm. Drill the hole to the required depth. Watch the drill, and when it begins to come through, decrease the speed. Hold the drill up by hand so that it will not drop onto the work.

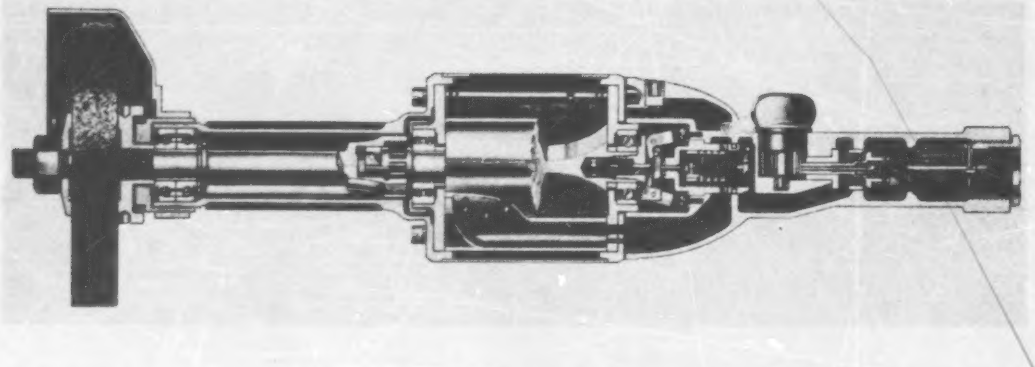
PNEUMATIC GRINDER

The pneumatic grinder, shown in figure 4-6, operates on the same basic principle as the pneumatic drill. It can be equipped with either a grinding wheel or a wire bristle wheel. After attaching the appropriate wheel, perform the preliminary steps required to connect the pneumatic grinder. Always run this machine so the grinding surface of the wheel is square with the surface of the material being ground.



11.6

Figure 4-5.—Heavy-duty pneumatic drill and stand.



11.8X

Figure 4-6.—Sectional view of a pneumatic grinder.

Pneumatic tools must have thorough lubrication. The moving parts of a pneumatic tool are very closely fitted; if proper lubrication is neglected, they wear rapidly and in a short time fail to work.

Valves and pistons on pneumatic hammers require a light machine oil; since the compressed air comes directly in contact with these parts, it has a tendency to drive the lubricant out through the exhaust.

When working steadily with a pneumatic tool, you should check the lubricator regularly to make certain there is ample lubricant available and empty the filter assembly when needed. On low-pressure compressed air systems that do not have the filter regulator and lubricator assembly installed, you should disconnect the airhose every hour or so and squirt a few drops of light oil into the airhose connection. If you use heavy oil, you will have to clean your tool in cleaning solvent to loosen the gummy substance. You will then have to blow out the tool with air, lubricate it with a light oil, and go back to work. Keep your pneumatic tools clean and lubricated and you will have fewer operating troubles.

When operating portable power tools, observe applicable safety precautions. A partial list of safe practices follows:

1. Always wear your goggles when working with these tools.
2. Do not allow any of these tools to run out of hand. The pneumatic grinder especially will want to "walk" away from the point you want to grind.
3. Always stand so that your feet won't slip while you are working and so that you are properly balanced.
4. Apply the grinding wheel to the work with gentle pressure. Sudden forcing may cause the wheel to disintegrate. As you complete the work, ease up on the pressure.
5. With all pneumatic tools, do not allow the airhose to become kinked.
6. When using an electric tool, make sure that the tool is properly grounded. Use only 3-wire grounded cords and plugs.
7. When an extension cord must be used in addition to the cord on an electric tool, make sure the extension cord is not energized when the tool plug is inserted in or removed from the extension cord. Use only 3-wire cord and grounded plugs.

PNEUMATIC PAVEMENT BREAKER

A PNEUMATIC PAVEMENT BREAKER (fig. 4-7) may be used on construction projects to demolish structures made of concrete, brick, asphalt, and the like. It is also used for general rock breaking. With attachments, it can be used for digging and tamping as well.

Five attachments for the pavement breaker are the moil point, chisel point, tamper, pick, and spade. (See fig. 4-7.) The moil point is a device for breaking through concrete, stone, or other dense and abrasive material. The chisel point will cut asphalt, frozen ground, or extremely hard earth. The tamper is used to compact loose material.

The spade, shaped like a garden spade, is used for digging trenches, preparing footings or foundations, digging caissons, or general digging that is too difficult and slow for an ordinary hand spade. The pick will dig into frozen ground, cemented gravel, or other material too hard to be penetrated by the spade.

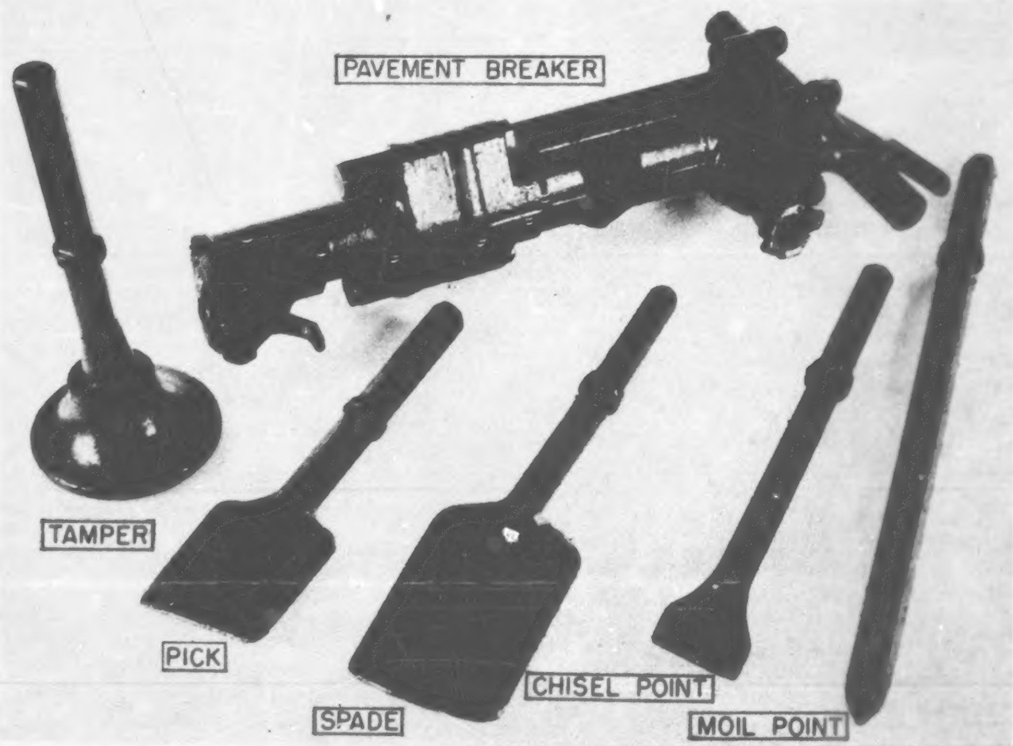
Operation

Pneumatic tools are simple to operate, and the average SEABEE can be taught to operate any of them in a relatively short time. In most cases, however, operators have little mechanical knowledge, so close supervision is required.

Since pneumatic tools are heavy and vibrate a lot during use, they tend to tire out their operators, especially the inexperienced ones. The operators should be strong and in good physical condition.

Hold the pavement breaker down while it is in operation, but use only sufficient pressure to guide the tool and keep it in place. Leaning heavily on the pavement breaker will only shorten the stroke of the tool attachment and result in less work being performed.

The shank of each attachment used with the pavement breaker must be the correct size. Using improper shank sizes will reduce the effectiveness of the blow and damage the pavement breaker.



127.267

Figure 4-7.—Pneumatic pavement breaker and accessories.

Pavement breakers can best be operated in tandem. In operating, take only small bites (4 to 8 inches behind the working face). If a moil point becomes stuck, use the second breaker to break the material binding the point. When the breaker is being used singly and the point becomes stuck, take the pavement breaker off and use another point to free the stuck point.

Keep the work area clear of broken material so that it does not interfere with efficient operation of the tool.

Make sure you are using the right attachment. Trying to drill holes with the moil point will result in breaking the point. The chisel point issued with the breaker is designed for cutting asphalt and soft materials. If it is used for breaking concrete, the point will be damaged beyond repair.

A careless operator can quickly break the tool latch retainer bolt by not shutting off the tool when the moil point breaks through concrete. When this happens the front head bounces on the concrete, resulting in a broken retainer bolt.

Maintenance

With proper maintenance, a pavement breaker can be kept in good operating condition. It certainly helps to sharpen the points of all attachments, and to keep them sharp. Check the airhose connections to the pavement breaker often to make sure no air is escaping. Check to see that all nuts and bolts are tight.

Safety Precautions

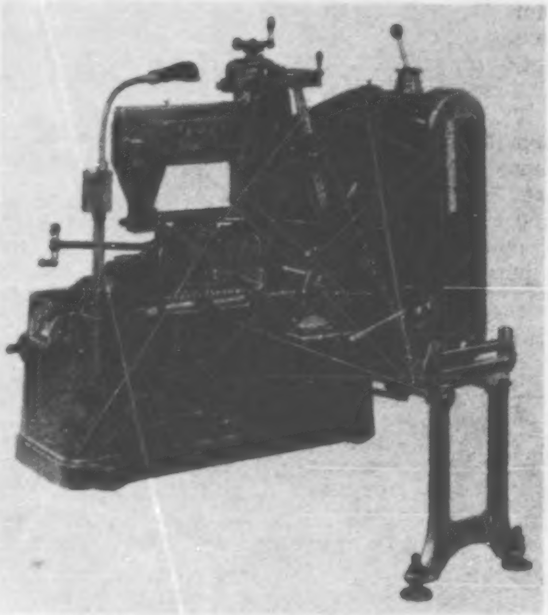
Make sure you exercise care in working with pneumatic pavement breakers or other types of pneumatic tools and accessories. Some general precautions to bear in mind are given below.

The operators of pneumatic tools should wear goggles to protect the eyes from chips and dust, and use the necessary personal protective devices.

Lay down pneumatic tools in such a manner that no harm can be done if the switch is accidentally tripped. Do not leave an idle tool in a standing position.

Shut off and exhaust pressure from the line before disconnecting the line from the tool.

The airhose must be suitable to withstand the pressure required for the tool. A leaking or defective hose must be removed from service. Hose should not be laid over ladders, steps, or sidewalks in such a manner as to create a tripping hazard. Where the hose is run through doorways, the hose should be protected against damage by the door edge. The hose should be laid between the operator's legs while he is using the pneumatic tool.



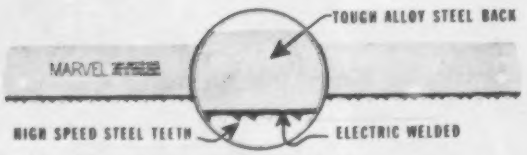
11.18X

Figure 4-8. — Power hacksaw.

POWER HACKSAWS

The power hacksaw is found in all (except the smallest) shops. It is used for cutting bar stock, pipe, tubing, or other metal stock. The power hacksaw, shown in figure 4-8, consists of a base, a mechanism for causing the saw frame to reciprocate, and a clamping vise for holding the stock while it is being sawed. The capacity designation of this power hacksaw is 4" x 4", which means it can handle material up to 4 inches in width and 4 inches in height.

There are three types of feed mechanisms: mechanical, hydraulic, and gravity. Mechanical feed ranges from 0.001 to 0.025 inch per stroke,



11.19X
Figure 4-9.— Power hacksaw blade.

depending upon the class and type of material being cut. Hydraulic feed normally exerts a constant pressure, but is so designed that when hard spots are encountered the feed is automatically stopped or shortened to decrease the pressure on the saw until the hard spot has been cut through. In gravity feed, weights on the saw frame can be shifted to increase or decrease the pressure of the saw blade on the material being cut. With each type of feed mechanism, the blade lifts clear of the work during the return stroke.

Hacksaw Blades

The blade shown in figure 4-9 is especially designed for use with the power hacksaw. It is made with a tough alloy steel back and high speed steel teeth, a combination which gives both a strong blade and a cutting edge suitable for high speed sawing.

Hacksaw blades vary in pitch, which is defined as the number of teeth per inch. The correct pitch of teeth for a particular job is determined by the size of the section, and the material to be cut. Use coarse pitch for wide, heavy sections in order to provide ample chip clearance. For thinner sections, use a blade whose pitch will keep two or more teeth in contact with the work so that the teeth will not straddle the work. Such straddling will strip the teeth. In general, you should select blades as indicated below.

Coarse (4 teeth per inch), for soft steel, cast iron, and bronze.

Regular (6 to 8 teeth per inch), for annealed high carbon steel and high speed steel.

Medium (10 teeth per inch), for solid brass stock, iron pipe, and heavy tubing.

Fine (14 teeth per inch), for thin tubing and sheet metals.

Speeds and Coolants

Speeds on hacksaws are stated in strokes per minute (spm). Count only those strokes which cause the blade to come in contact with the stock. Speed is usually changed by means of a gear shift lever. There may be a card attached to your equipment or near it, stating recommended speeds for cutting various metals. The following speeds, however, can usually be used in cutting the metals listed below.

136 spm — Cold rolled or machine steel, brass, and soft metals.

90 spm — Alloy steel, annealed tool steel, and cast iron.

60 spm — High speed steel, unannealed tool steel, and stainless steel.

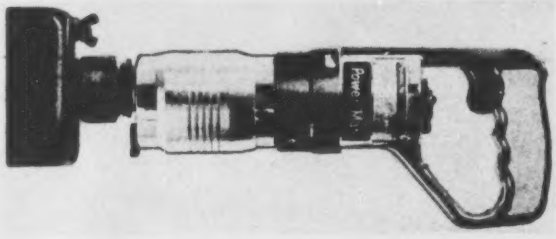
Cast iron should be cut entirely dry, but a coolant should be used when all other materials are cut. A suitable coolant for most metals is a solution of water and enough soluble oil to make the solution white. The coolant not only prevents overheating of the blade and stock but also serves to increase the cutting rate.

When you operate the power hacksaw, place the pipe in the clamping device, adjusting it so that the cutting off mark is in line with the blade. Next, turn the vise lever to clamp the pipe in place, being sure that the material is held tightly, and then set the stroke adjustment. Before you start the machine, check to see that the blade is NOT touching the pipe. Blades can be broken if you do not follow this rule. Feed the blade slowly into the work, and adjust the coolant nozzle so that it directs the fluid over the saw blade. Safety precautions to be observed while operating this tool are posted in the shop. Read and observe them.

POWER-ACTUATED TOOLS

A number of different kinds of tools which utilize explosive charges to drive fastening devices are widely used. These tools are sometimes called stud guns, stud-type cartridge guns, builder's guns, or powder-actuated guns. Among the number of different tools, there are two basic types in use by the Navy. One type (fig. 4-10) is a high-velocity device in which the fastener is shot down the barrel of the tool by a relatively powerful powder charge. Another type (fig. 4-11) is a power-assisted hammer-drive tool operating on the low-velocity principle. The manufacturers of the different types of tools provide detailed instructions for the safe and effective use of their products so follow their instructions closely at all times.

The powder-actuated tool in figure 4-10 covers the complete range of powder-actuated fastening, providing light, medium- and heavy-duty anchoring of 1/4'' and 3/8'' headed pins and threaded studs in masonry and steel. (See figures 4-12 and 4-13 for the proper pins and studs.) The barrel on this type powder-actuated tool can be changed in a matter of seconds, so as to adapt the tool to either of the kits described in figures 4-14 and 4-15. This can be a difficult and dangerous tool to use, so be sure to study the manufacturer's manual beforehand.

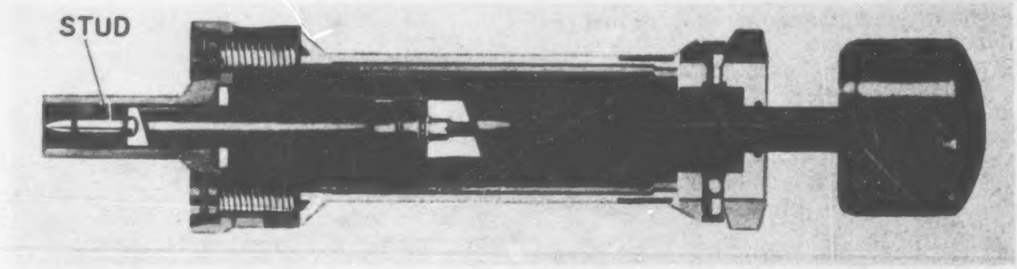


133.78
Figure 4-10.—Power-Mate stud driver.

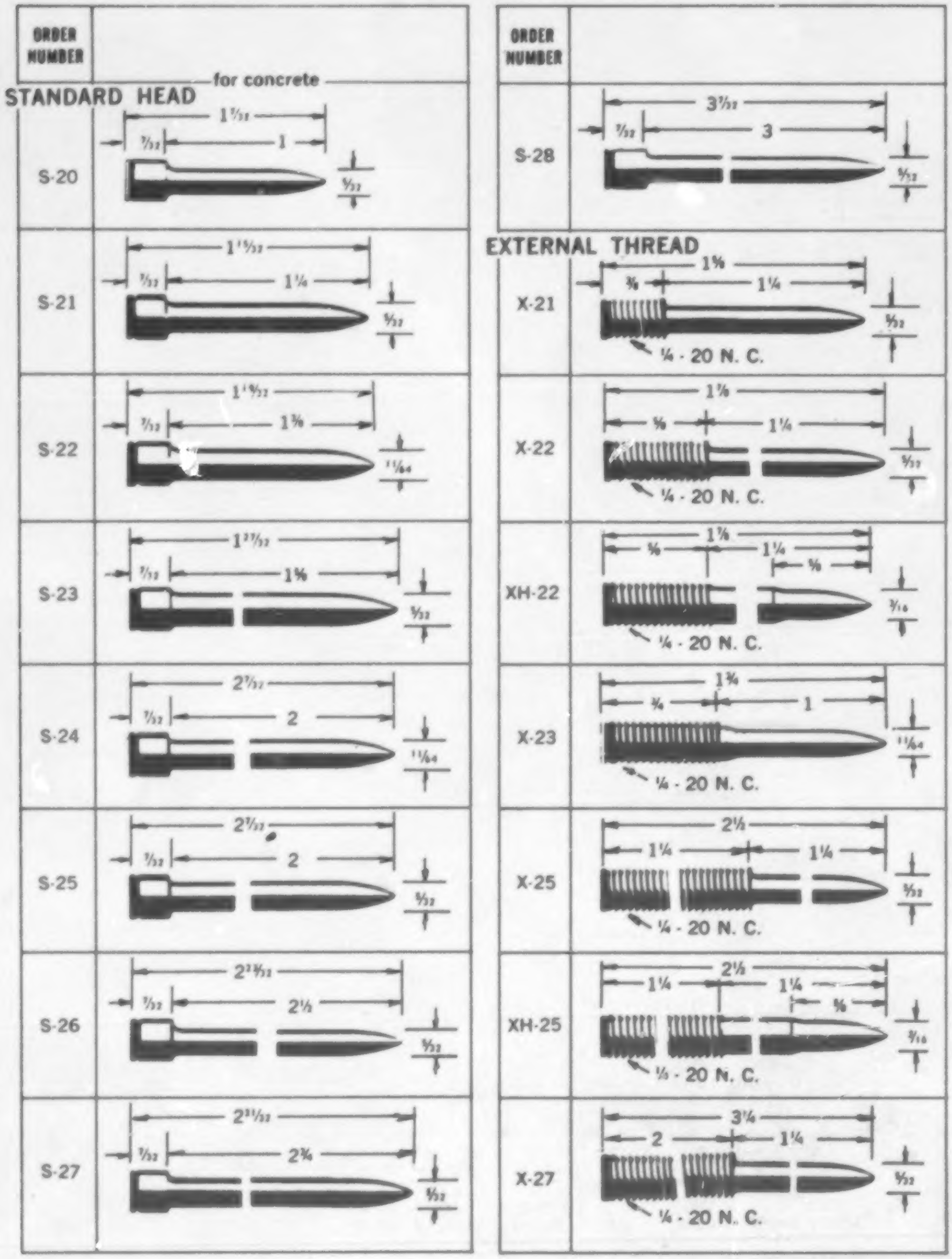
The power-assisted stud driver shown in figure 4-11 may be used either with or without the powder charge. When the powder charge is used, it acts as a booster for a hammer blow. Without a powder charge, the device may be used as an ordinary hammer-drive tool. The stud, shown in figure 4-11, is seated, guided, and controlled in the recessed piston. The rimfire booster blank, which contains a small slow-burning charge of powder, is seated backwards above the piston and below the ram, which is hit with the hammer. Rather than shooting the stud at high velocity, the captive, heavy-mass piston pushes the stud into the work at a relatively low velocity. The piston guides the head of the fastener from the start to the finish of driving. A washer or guide disk near the end of the pin or stud guides the fastener during operation. Since the piston is captive, no energy is imparted to the fastener after the piston stops travelling. The depth of penetration varies with the type of piston and fastener used. Overpenetration is prevented by the positive control of the fastener exercised by the piston and guide disk. The hazards of using the high-velocity gun are eliminated by the use of this type of tool; special shields or protective devices are not generally considered necessary.

The power-assisted hammer-drive tool may be used in any position: on the deck, on the wall, in the overhead. It may be used to fasten almost any type of construction material to any other type. Figure 4-16 shows a wood-to-metal connection; figure 4-17, a metal-to-concrete connection.

Figure 4-18 shows some of the other types of widely used pins and studs. The tool illustrated in figure 4-11 will accommodate fasteners of up to 4-inch overall length. For most jobs you will need two pistons: one for pins and one for studs.

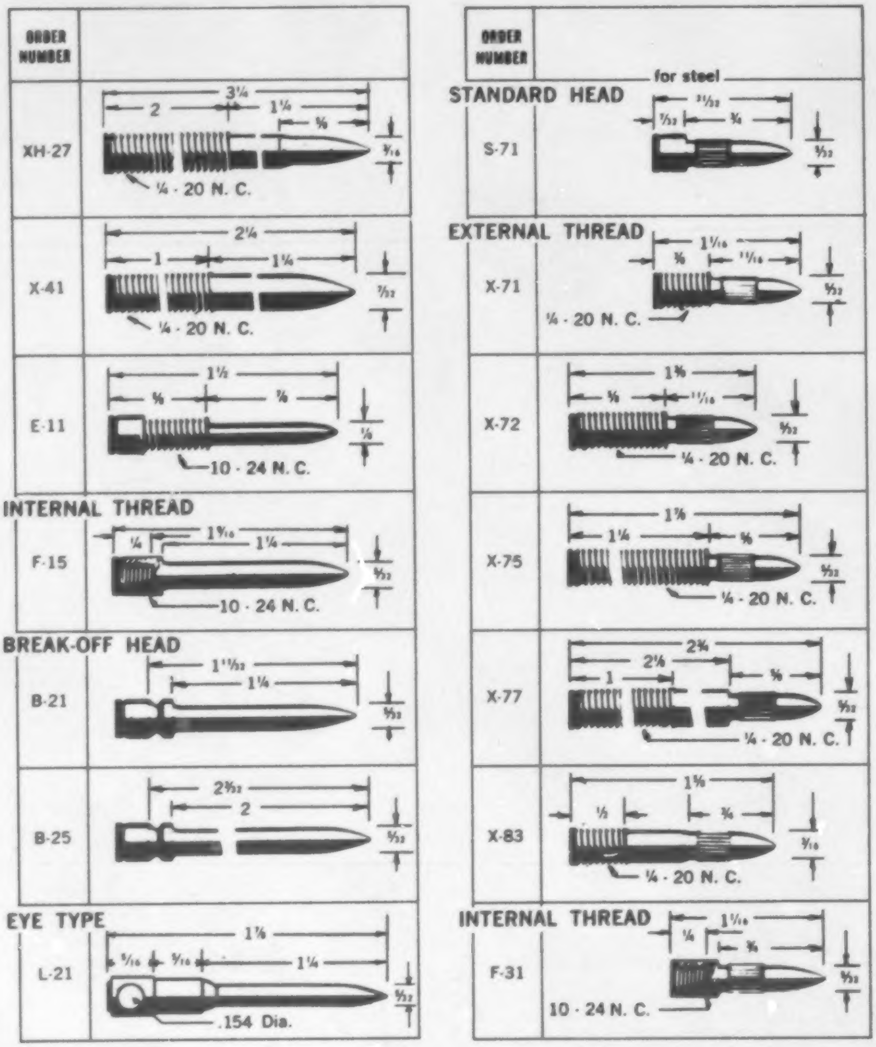


133.78X
Figure 4-11.—Cutaway view of power-assisted stud driver.


ORDER NUMBER
STANDARD HEAD
for concrete
S-20
1 7/32
7/32
1
9/32
S-21
1 15/32
7/32
1¼
9/32
S-22
1 19/32
7/32
1⅜
11/64
S-23
1 27/32
7/32
1⅝
9/32
S-24
2 7/32
7/32
2
11/64
S-25
2 7/32
7/32
2
9/32
S-26
2 23/32
7/32
2½
9/32
S-27
2 31/32
7/32
2¾
9/32
ORDER NUMBER
S-28
3 7/32
7/32
3
9/32
EXTERNAL THREAD
X-21
1⅝
⅜
1¼
9/32
¼ - 20 N. C.
X-22
1⅞
⅝
1¼
9/32
¼ - 20 N. C.
XH-22
1⅞
⅝
1¼
⅝
3/16
¼ - 20 N. C.
X-23
1¾
¾
1
11/64
¼ - 20 N. C.
X-25
2½
1¼
1¼
9/32
¼ - 20 N. C.
XH-25
2½
1¼
1¼
⅝
3/16
¼ - 20 N. C.
X-27
3¼
2
1¼
9/32
¼ - 20 N. C.

29.121.2

Figure 4-12.—1/4" headed pins and threaded studs.


ORDER NUMBER
XH-27
¼ - 20 N. C.
X-41
¼ - 20 N. C.
E-11
10 - 24 N. C.
INTERNAL THREAD
F-15
10 - 24 N. C.
BREAK-OFF HEAD
B-21
B-25
EYE TYPE
L-21
.154 Dia.
ORDER NUMBER
STANDARD HEAD
for steel
S-71
EXTERNAL THREAD
X-71
¼ - 20 N. C.
X-72
¼ - 20 N. C.
X-75
¼ - 20 N. C.
X-77
¼ - 20 N. C.
X-83
¼ - 20 N. C.
INTERNAL THREAD
F-31
10 - 24 N. C.

22 CALIBER STANDARD—Wad

ORDER NUMBER	LOAD LEVEL NUMBER	WAD COLOR
22w3	3	Green
22w4	4	Yellow
22w5	5	Red
22w6	6	Purple

22 CALIBER SPECIAL-Wad

ORDER NUMBER	LOAD LEVEL NUMBER	WAD COLOR
22w7	7	Gray
22w8	8	Brown

25 CALIBER STANDARD—Wad

ORDER NUMBER	LOAD LEVEL NUMBER	WAD COLOR
25w6	6	Purple
25w7	7	Gray

25 CALIBER STANDARD —Crimp

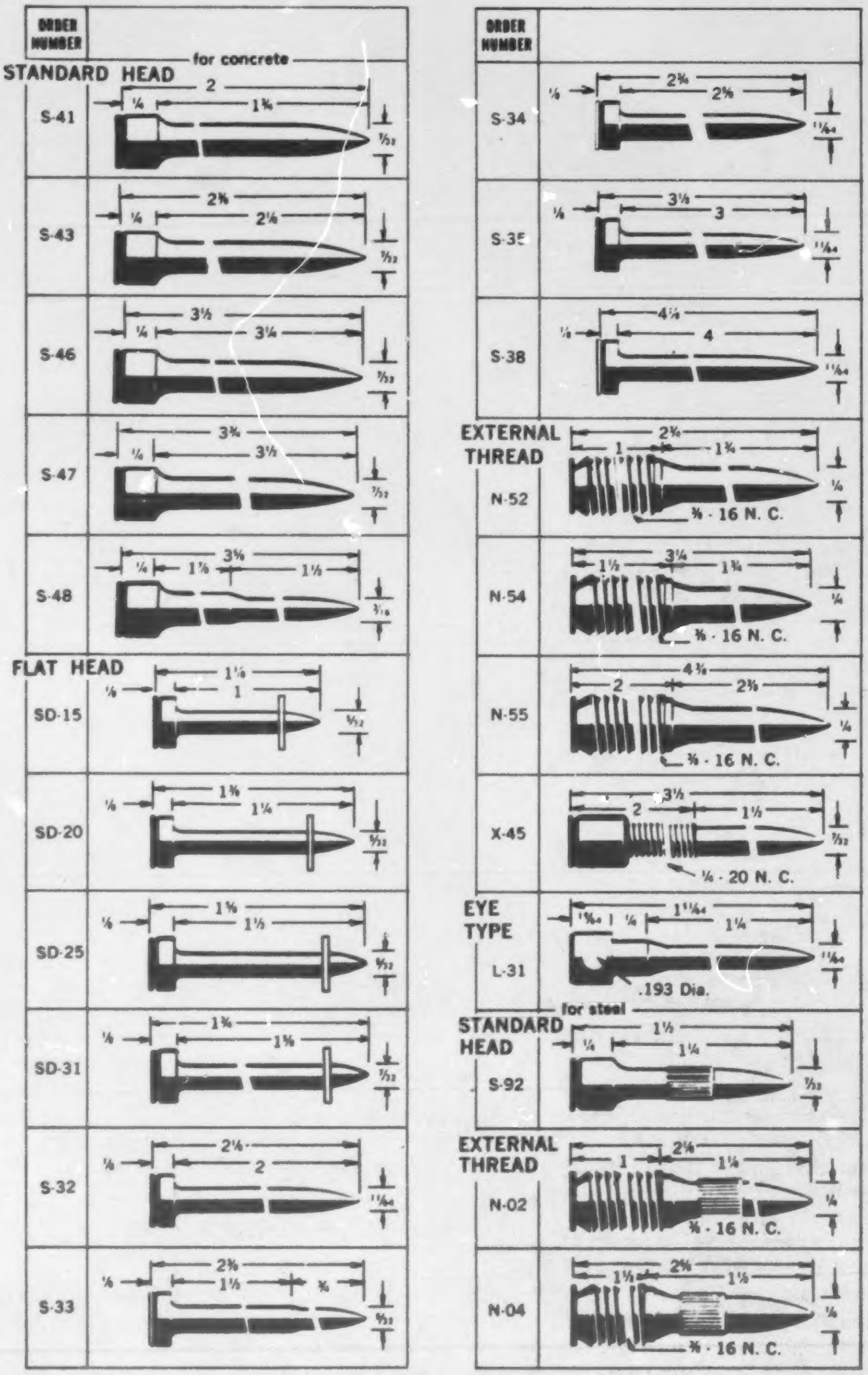
ORDER NUMBER	LOAD LEVEL NUMBER	HEAD COLOR
25c1	1	Gray
25c2	2	Brown
25c3	3	Green

32 CALIBER STANDARD—Wad

ORDER NUMBER	LOAD LEVEL NUMBER	WAD COLOR
32w8	8	Brown
32w9	9	Green
32w10	10	Yellow
32w11	11	Red

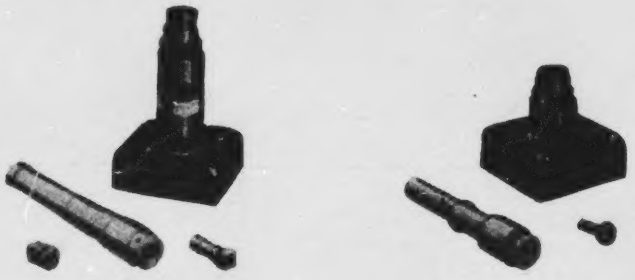
29.121.2

Figure 4-12.—1/4" headed pins and threaded studs—continued.


ORDER NUMBER
for concrete
STANDARD HEAD
S-41
2
1/4
1 3/4
7/32
S-43
2 3/8
1/4
2 1/8
7/32
S-46
3 1/2
1/4
3 1/4
7/32
S-47
3 3/4
1/4
3 1/2
7/32
S-48
3 3/8
1/4
1 7/8
1 1/2
3/16
FLAT HEAD
SD-15
1 1/8
1/8
1
5/32
SD-20
1 3/8
1/8
1 1/4
5/32
SD-25
1 5/8
1/8
1 1/2
5/32
SD-31
1 3/4
1/8
1 5/8
7/32
S-32
2 1/8
1/8
2
11/64
S-33
2 5/8
1/8
1 1/2
3/4
5/32
ORDER NUMBER
S-34
1/8
2 3/4
2 5/8
11/64
S-35
1/8
3 1/8
3
11/64
S-38
1/8
4 1/8
4
11/64
EXTERNAL THREAD
N-52
2 3/4
1
1 3/4
1/4
3/8 - 16 N. C.
N-54
3 1/4
1 1/2
1 3/4
1/4
3/8 - 16 N. C.
N-55
4 3/8
2
2 3/8
1/4
3/8 - 16 N. C.
X-45
3 1/2
2
1 1/2
7/32
1/4 - 20 N. C.
EYE TYPE
L-31
1 11/64
13/64
1/4
1 1/4
11/64
.193 Dia.
for steel
STANDARD HEAD
S-92
1 1/2
1/4
1 1/4
7/32
EXTERNAL THREAD
N-02
2 1/4
1
1 1/4
1/4
3/8 - 16 N. C.
N-04
2 5/8
1 1/2
1 1/8
1/4
3/8 - 16 N. C.

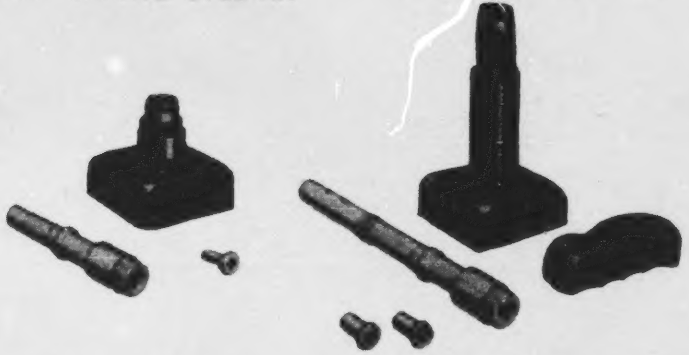
29.121.3

Figure 4-13.— 3/8'' headed pins and threaded studs.



K-1 CAPTIVE STUD KIT

K-2 LIGHT DUTY KIT



K-3 MEDIUM DUTY KIT

K-4 MEDIUM & HEAVY DUTY KIT

133.340.1

Figure 4-14.—Stud driver kits.

However, if you have studs with two different thread lengths (such as shown in fig. 4-18), you will need a separate piston for each thread length. There are many other types of fasteners for special requirements. They may be used in the hammer-drive tool if you have the special piston that is needed for the fastener.

Powder-actuated tools should be operated, repaired, serviced, and handled only by CE's who have been trained and certified by the manufacturer, his authorized representative, or Navy Department certified instructors. Therefore, special authorization or licensing is required before you are permitted to use most types of stud guns. Never attempt to use one of these tools without proper authorization and instruction. Be sure you follow the manufacturer's instructions. Never use the powder charge in an explosive atmosphere. Lastly, remove any defective tools or parts from service immediately.

AIR COMPRESSORS

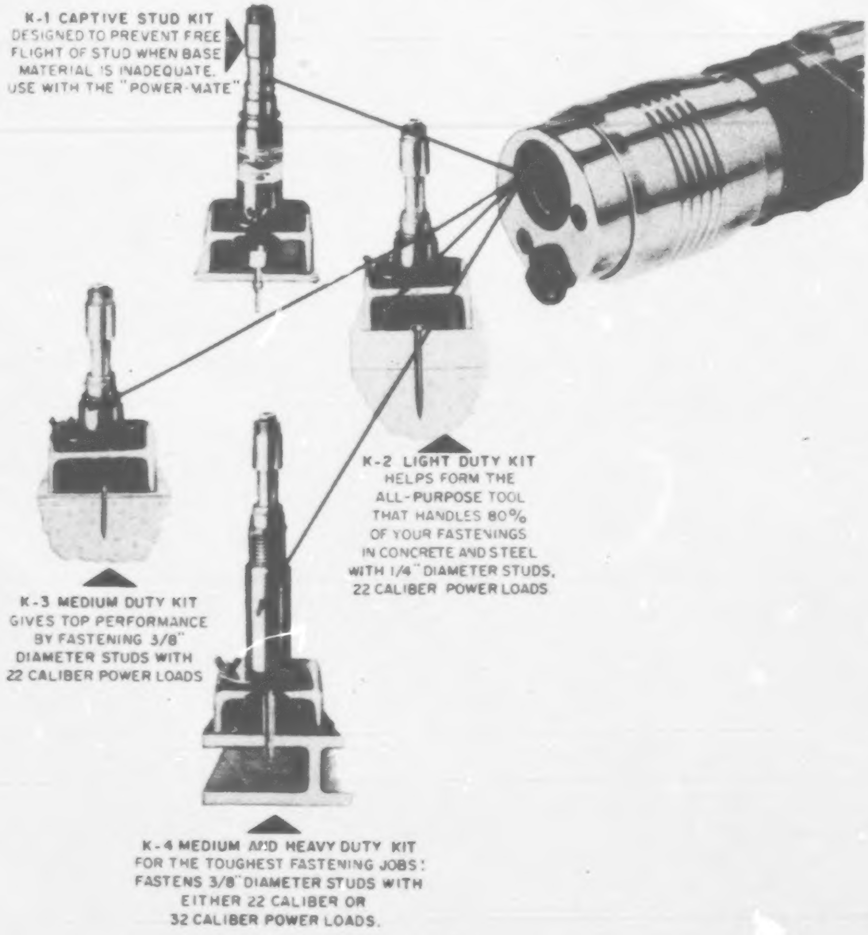
A compressor is a machine that increases the pressure of air by reducing its volume. A compressor consists of a driving unit, a compressor unit, and accessory equipment. The driving unit provides power to operate the compressor and may be a gasoline or diesel engine. Compressors are governed by a pressure control system adjusted to compress air to a maximum pressure of 100 pounds per square inch.

COMPRESSED AIR SYSTEM

A compressed air system consists of one or more compressors, each with the necessary power source, control of regulation, intake air filter, aftercooler, air receiver, and connecting piping, together with a distribution system to carry the air to points of use.

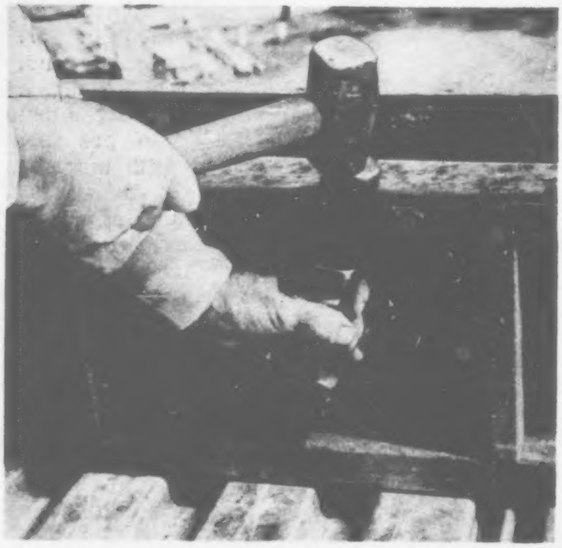
The object of installing a compressed air system is to provide sufficient air at the work area at pressures adequate for efficient operation of pneumatic tools being used.

Many construction jobs require more cubic feet of air per minute than any one compressor will produce. Terrain conditions often create problems of distance from compressor to operating tool. Since the air line hose issued with the compressor causes considerable line loss at distances further than 200 feet, a system has been devised for efficient transmission of compressed air over longer distances. This system is air manifolding (fig. 4-19). An air manifold is a large diameter pipe used to transport compressed air from one or more compressors over a distance with a small friction line loss. In construction work, air manifolds are usually constructed of 6-inch diameter pipe. A pipe of this size can carry 1200 cubic feet per minute of air (output from two 600 cfm air compressors) at 100 pounds per square inch with less than .035 pound pressure loss per 100 linear feet. One or more compressors pump air into the manifold and eventually pressurize it at 100 pounds per square inch; then air may be used

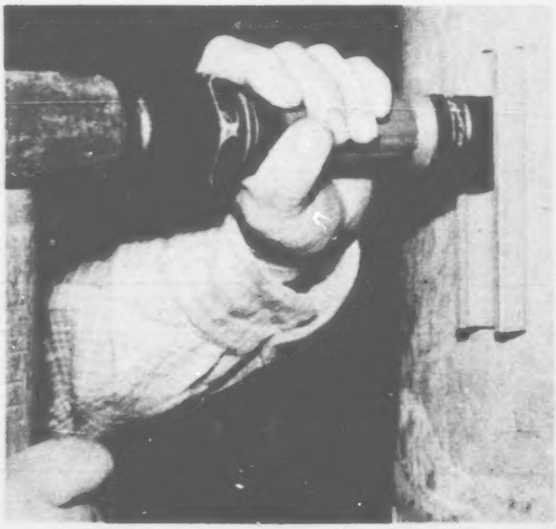

K-1 CAPTIVE STUD KIT
DESIGNED TO PREVENT FREE FLIGHT OF STUD WHEN BASE MATERIAL IS INADEQUATE. USE WITH THE "POWER-MATE"
K-2 LIGHT DUTY KIT
HELPS FORM THE ALL-PURPOSE TOOL THAT HANDLES 80% OF YOUR FASTENINGS IN CONCRETE AND STEEL WITH 1/4" DIAMETER STUDS, 22 CALIBER POWER LOADS
K-3 MEDIUM DUTY KIT
GIVES TOP PERFORMANCE BY FASTENING 3/8" DIAMETER STUDS WITH 22 CALIBER POWER LOADS
K-4 MEDIUM AND HEAVY DUTY KIT
FOR THE TOUGHEST FASTENING JOBS: FASTENS 3/8" DIAMETER STUDS WITH EITHER 22 CALIBER OR 32 CALIBER POWER LOADS.

133.340.2

Figure 4-15.—Purpose of individual stud driver kits.



133.79X
Figure 4-16.—Toenailing wood to hollow metal decking.



133.81X
Figure 4-17.—Fastening channel to concrete.

at any point along the manifold by installing outlet valves and connecting air lines and pneumatic tools.

COMPRESSOR OPERATION AND MAINTENANCE

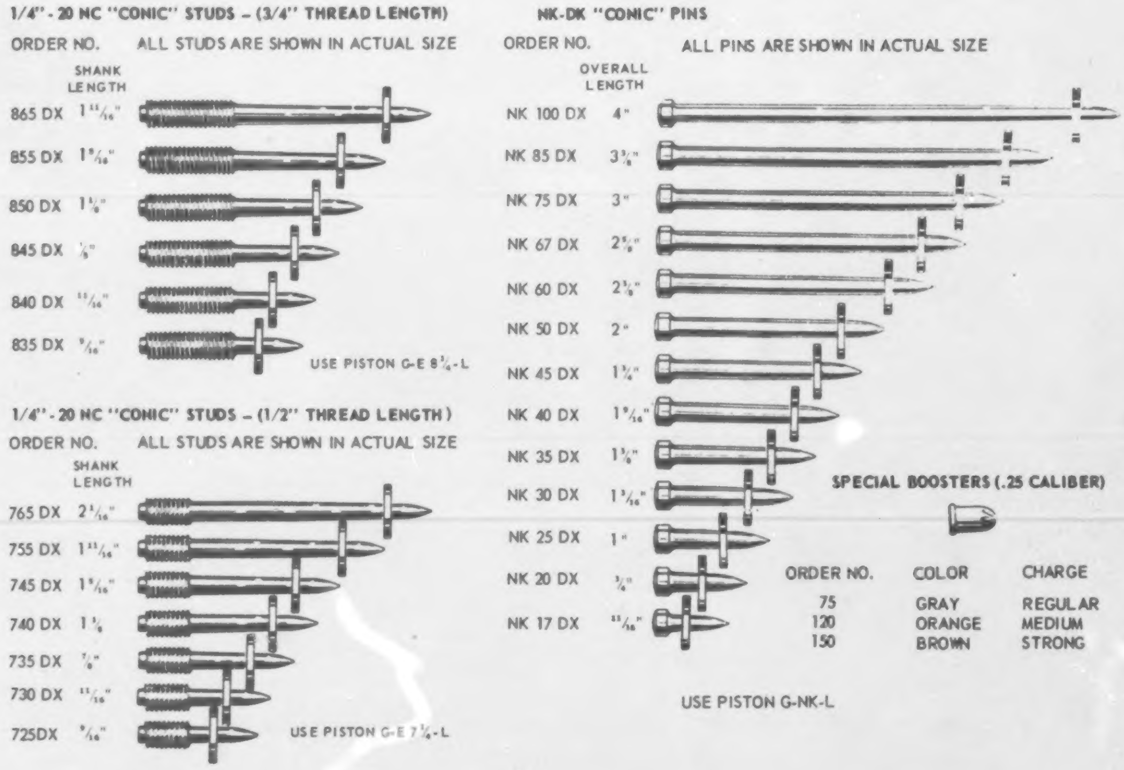
The following paragraphs will give general instructions on operating and maintaining air compressor units. One of several types that SEABEES operate and maintain is the Worthington 600-cfm portable compressor (fig. 4-20) which is diesel-engine driven. The complete unit is equipped with springs, tires, and a drawbar. The drawbar is normally located on the compressor end of the chassis. When the unit is coupled to a self-propelled crawler drill supplying air for its tramming motors, this drawbar location keeps the radiator and oil cooler further away from the cloud of dust which the crawler rig can create.

The compressor unit must be located on a reasonably level area. The design of this unit permits a 15-degree lengthwise and a 15-degree sidewise limit on out-of-level operation. The limits are placed on the engine, not the compressor. When the unit is to be operated out-of-level, it is important: (1) to keep the engine crankcase oil level near the high level mark (with the unit level), and (2) to have the compressor oil gage show nearly full (with the unit on the level).

An instruction plate similar to the one shown in figure 4-21 is attached to the unit. Notice that this plate refers you to the manufacturer's engine and compressor manuals for detailed instructions.

Operating the Clutch

The clutch should remain engaged at all times except during engine warmup or tuneup periods. In this way its compression springs and shifter mechanism are not under a constant strain. The compression springs hold the friction disks in the engaged position; the shifter mechanism forces the disks apart hydraulically against the spring compression to disengage the clutch. A built-in safety interlock prevents the clutch


1/4" - 20 NC "CONIC" STUDS – (3/4" THREAD LENGTH)
ORDER NO.
ALL STUDS ARE SHOWN IN ACTUAL SIZE
SHANK LENGTH
865 DX 1 11/16"
855 DX 1 9/16"
850 DX 1 3/8"
845 DX 7/8"
840 DX 11/16"
835 DX 9/16"
USE PISTON G-E 8 1/4-L
1/4" - 20 NC "CONIC" STUDS – (1/2" THREAD LENGTH)
ORDER NO.
ALL STUDS ARE SHOWN IN ACTUAL SIZE
SHANK LENGTH
765 DX 2 3/16"
755 DX 1 11/16"
745 DX 1 5/16"
740 DX 1 1/8
735 DX 7/8"
730 DX 11/16"
725DX 9/16"
USE PISTON G-E 7 1/4-L
NK-DK "CONIC" PINS
ORDER NO.
ALL PINS ARE SHOWN IN ACTUAL SIZE
OVERALL LENGTH
NK 100 DX 4"
NK 85 DX 3 3/8"
NK 75 DX 3"
NK 67 DX 2 5/8"
NK 60 DX 2 3/8"
NK 50 DX 2"
NK 45 DX 1 3/4"
NK 40 DX 1 9/16"
NK 35 DX 1 3/8"
NK 30 DX 1 3/16"
NK 25 DX 1"
NK 20 DX 3/4"
NK 17 DX 11/16"
SPECIAL BOOSTERS (.25 CALIBER)
USE PISTON G-NK-L

ORDER NO.	COLOR	CHARGE
75	GRAY	REGULAR
120	ORANGE	MEDIUM
150	BROWN	STRONG

29.121X

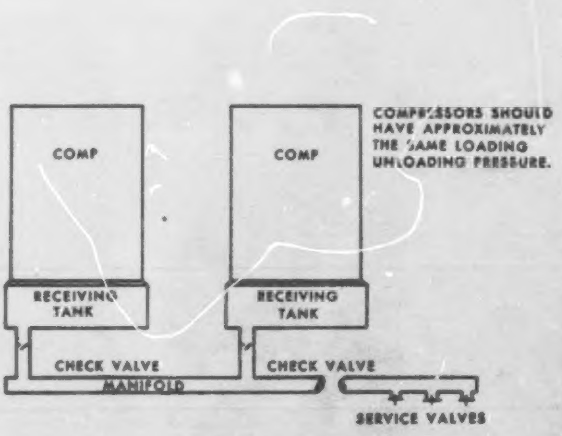
Figure 4-18.—Studs and pins.

from being engaged or disengaged while the engine is running.

When the engine is stopped, the clutch sleeve can be pushed down easily to expose a knurled knob which is turned to engage and disengage the engine clutch. Never try to move the clutch sleeve and turn the knob when the engine is running. Always shut down the engine before engaging or disengaging the clutch.

To disengage the clutch, turn the knob clockwise as far as it will go. Pressurize the clutch shifter by stroking the hydraulic pump handle. A built-in pressure relief valve prevents overpressurizing.

To engage the clutch, turn the knurled knob counterclockwise three or four turns until the pump handle offers little resistance to pumping. Leave the knob in this position.


COMP
COMP
COMPRESSORS SHOULD HAVE APPROXIMATELY THE SAME LOADING UNLOADING PRESSURE.
RECEIVING TANK
RECEIVING TANK
CHECK VALVE
CHECK VALVE
MANIFOLD
SERVICE VALVES

115.385

Figure 4-19.—Methods of manifolding compressors.

Starting the Unit

The following steps should be taken when starting the engine during mild or warm weather:

1. Open service valves about one quarter—not wide open.

NOTE: The reason for starting with the service valves partly open is that they aid in quicker warmup of the compressor oil.

2. Make sure the clutch is in engaged position.

3. Position the low-pressure, engine-oil-system safety-control-knob to ON (fig. 4-22).

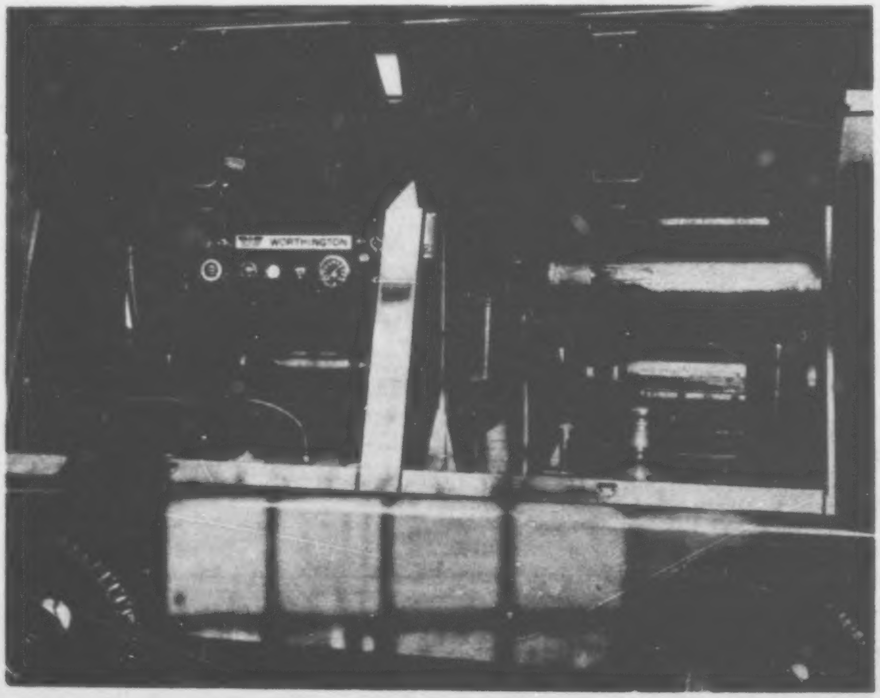
4. Turn the ignition switch to start position. Immediately after the engine starts, release the ignition switch. If the engine fails to fire within 30 seconds, release the ignition switch and allow the starting motor to cool off for a few moments before trying the starter again.

5. With the engine running, check the engine oil pressure gage. If no pressure is indicated, turn the engine off. When the oil pressure goes above 22 psi, continue to operate the engine and check the low-pressure engine oil switch. The knob on this switch should be in the RUN position.

NOTE: The engine oil pressure gage indicates erratically until the engine oil warms up.

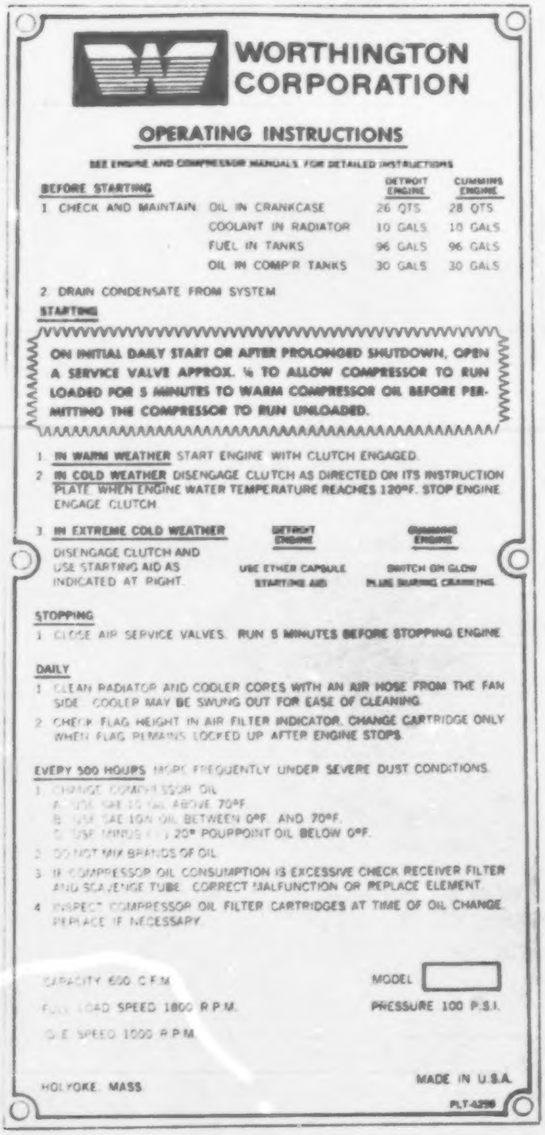
6. Open the side curtains on both sides of the engine enclosure and leave them open. Flow of air through the oil cooler and engine radiator will be impeded if the side curtains are closed while the engine is running.

7. After the engine has run about 3 minutes, check the engine coolant temperature gage. The gage should indicate less than 210° F. If the gage is showing more than 210° F, SHUT OFF THE ENGINE.



115.377X

Figure 4-20.—Worthington 600 cfm portable, rotary air compressor.



WORTHINGTON CORPORATION

OPERATING INSTRUCTIONS

SEE ENGINE AND COMPRESSOR MANUALS FOR DETAILED INSTRUCTIONS

BEFORE STARTING

		DETROIT ENGINE	CUMMINS ENGINE
1. CHECK AND MAINTAIN	OIL IN CRANKCASE	26 QTS	28 QTS
	COOLANT IN RADIATOR	10 GALS	10 GALS
	FUEL IN TANKS	96 GALS	96 GALS
	OIL IN COMP'R TANKS	30 GALS	30 GALS

2. DRAIN CONDENSATE FROM SYSTEM

STARTING

ON INITIAL DAILY START OR AFTER PROLONGED SHUTDOWN, OPEN A SERVICE VALVE APPROX. ¼ TO ALLOW COMPRESSOR TO RUN LOADED FOR 5 MINUTES TO WARM COMPRESSOR OIL BEFORE PERMITTING THE COMPRESSOR TO RUN UNLOADED.

1. IN WARM WEATHER START ENGINE WITH CLUTCH ENGAGED.
2. IN COLD WEATHER DISENGAGE CLUTCH AS DIRECTED ON ITS INSTRUCTION PLATE. WHEN ENGINE WATER TEMPERATURE REACHES 120°F. STOP ENGINE ENGAGE CLUTCH.
3. IN EXTREME COLD WEATHER

	DETROIT ENGINE	CUMMINS ENGINE
DISENGAGE CLUTCH AND USE STARTING AID AS INDICATED AT RIGHT.	USE ETHER CAPSULE STARTING AID	SWITCH ON GLOW PLUG DURING CRANKING

STOPPING

1. CLOSE AIR SERVICE VALVES. RUN 5 MINUTES BEFORE STOPPING ENGINE.

DAILY

1. CLEAN RADIATOR AND COOLER CORES WITH AN AIR HOSE FROM THE FAN SIDE. COOLER MAY BE SWUNG OUT FOR EASE OF CLEANING.
2. CHECK FLAG HEIGHT IN AIR FILTER INDICATOR. CHANGE CARTRIDGE ONLY WHEN FLAG REMAINS LOCKED UP AFTER ENGINE STOPS.

EVERY 500 HOURS MORE FREQUENTLY UNDER SEVERE DUST CONDITIONS.

1. CHANGE COMPRESSOR OIL
   - A. USE SAE 10 OIL ABOVE 70°F.
   - B. USE SAE 10W OIL BETWEEN 0°F. AND 70°F.
   - C. USE MINUS (–) 20° POURPOINT OIL BELOW 0°F.
2. DO NOT MIX BRANDS OF OIL.
3. IF COMPRESSOR OIL CONSUMPTION IS EXCESSIVE CHECK RECEIVER FILTER AND SCAVENGE TUBE. CORRECT MALFUNCTION OR REPLACE ELEMENT.
4. INSPECT COMPRESSOR OIL FILTER CARTRIDGES AT TIME OF OIL CHANGE. REPLACE IF NECESSARY.

CAPACITY 600 C.F.M.
FULL LOAD SPEED 1800 R.P.M.
IDLE SPEED 1000 R.P.M.

MODEL ☐
PRESSURE 100 P.S.I.

HOLYOKE, MASS.

MADE IN U.S.A.
PLT-4299

115.378X
Figure 4-21.—Operating instruction plate.

8. After 5 minutes of operation, close the service valve and attach the hose or service line of the tool or device to be operated.

9. Open the service valves fully and start the work. After startup, the unit automatically provides compressed air at the discharge service valves. Only periodic checking of the gages on the instrument panel is then required.

10. When the engine is started during the day, after the first daily startup, the above warmup steps may be eliminated.

Stopping the Unit

When stopping the unit at the end of the day's run, take the following steps:

1. Close the service valves and permit the engine to run at idle for 5 minutes. This will allow the engine coolant temperature to level off and the entire unit to cool down.

2. Turn the ignition switch to the OFF position.

Cold Weather Starting

The following steps should be completed during cold weather starting:

1. Disengage the clutch. This will permit engine warmup at idling speed.

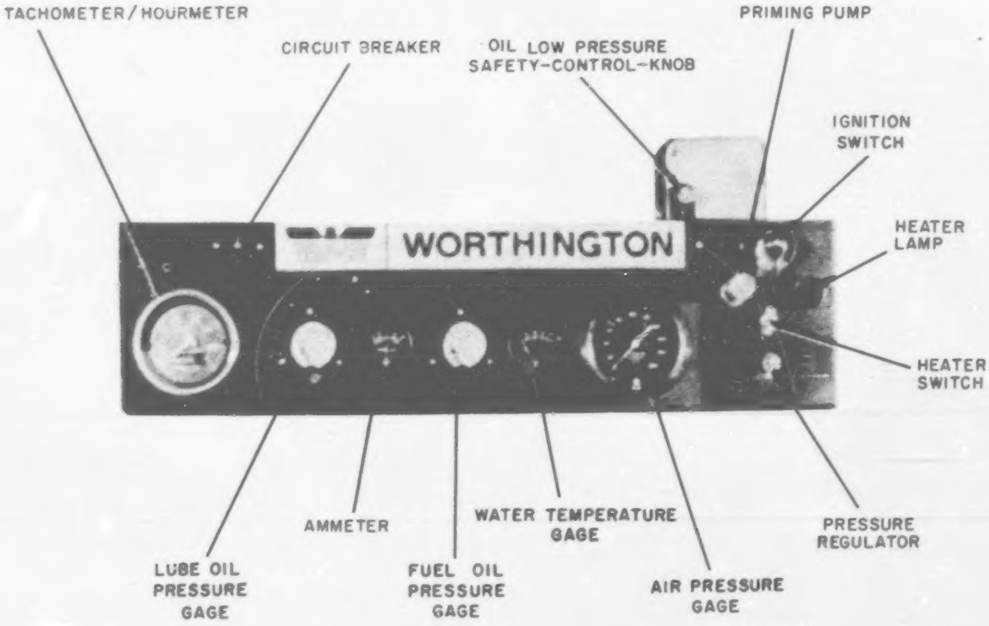
2. Start the engine using the heater switch and priming pump in accordance with the engine manual.

3. Warm the engine until the engine coolant temperature reaches 120° F. Leaving the side curtains closed for a few minutes helps the engine to warm up.

4. Turn the ignition switch to OFF.

5. When the engine has stopped, engage the clutch and start the engine again with the service valves partly open. Be sure the side curtains are open.

6. When the compressor has run for several minutes and the gages indicate normal operating conditions, connect up the tools and go to work.


TACHOMETER/HOURMETER
CIRCUIT BREAKER
OIL LOW PRESSURE SAFETY-CONTROL-KNOB
PRIMING PUMP
IGNITION SWITCH
HEATER LAMP
WORTHINGTON
HEATER SWITCH
PRESSURE REGULATOR
WATER TEMPERATURE GAGE
AMMETER
LUBE OIL PRESSURE GAGE
FUEL OIL PRESSURE GAGE
AIR PRESSURE GAGE

115.383X

Figure 4-22.—Instrument panel.

Lubricating the Unit

The lubrication chart in the operator's manual for the particular make and model of compressor you are operating will show you where the unit should be lubricated, how often to lubricate, and what lubricant to use. The frequency will vary depending upon operating conditions. Operating under abnormal conditions requires more frequent service.

CAUTION: Before servicing the compressor air system or compressor oil system, open the service valves to the atmosphere to relieve all pressure in the systems.

Servicing the Air Cleaner

A two-stage, dry-type air cleaner, installed inside the engine enclosure at the right rear, filters the intake air (fig. 4-23). Air is drawn into a first-stage element which causes nearly all the dust in the air to drop into a bin. Air then enters the second-stage element, a paper cartridge, where more dust is trapped and collected.

The dust bin should be removed by hand and emptied daily. Some models have a self-emptying dust bin that is piped into an aspirator in the exhaust pipeline, just beyond the muffler. When the aspirator is used, no alterations are allowed to be made to the engine muffler or exhaust pipe.

On the side of the air cleaner housing, there is mounted a service indicator. As the paper cartridge loads up with dust, a red indicator flag gradually rises in the window. When the cartridge is completely loaded, the window will show all red, and the flag will be locked in place. It is time to replace the paper cartridge. Discard the old cartridge and reset the red flag so that the window shows clear. Cleaning used paper cartridges is not recommended.

Drainage

Drain cocks are provided at the bottom of the compressor suction control and the engine speed control. These cocks should be left open when the unit is standing idle, particularly in freezing weather. They must be closed before the engine is started.

Drain any condensate which may have accumulated in the bottom of the oil storage tanks. A drain cock is provided on the piping at the bottom of the left hand oil storage tank. Open this cock and keep it open as long as water is draining out. Close the cock quickly when oil starts draining.

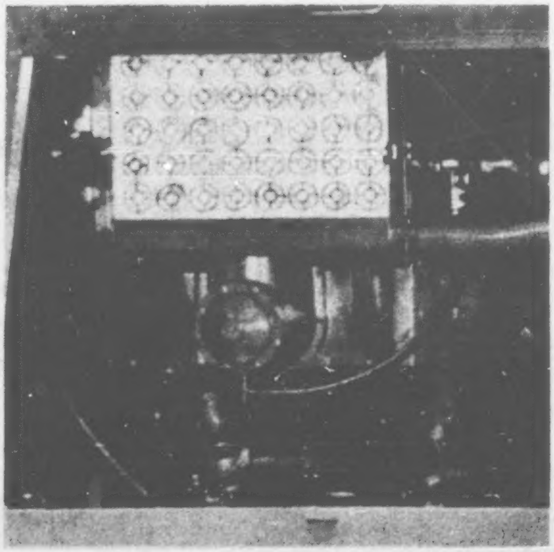
AIR COMPRESSOR SAFETY

General safety precautions for air compressors are as follows:

Be sure the air at intake is cool and free from flammable gases or vapors.

Do not permit wood or other flammable materials to remain in contact with the air discharge pipe.

Immediately secure a compressor if the temperature of the air discharged from any stage rises unduly or exceeds 400° F.



115.379X

Figure 4-23.—Air cleaner.

Never disable pressure gages except when they are to be removed for good reason.

Never kink a hose to stop the air flow. Keep the clamps on the hose tight.

When starting an air compressor, check the safety valves, pressure valves, and regulators to determine that they are working properly.

Do not leave the compressor after starting it unless you have made certain that the control, unloading, and governing devices are working properly.

Do not run an air compressor faster than the speed recommended by the manufacturer.

Use only the proper grade of oil recommended by the manufacturer, and avoid the application of too much oil. Use only oils which have high flashpoints to lubricate the air cylinders of air compressors.

Keep compressors, tanks, and accompanying piping clean to guard against oil vapor explosion. Clean intake air filters periodically.

Use only soapy water or suitable nontoxic, nonflammable solution for cleaning compressor intake filters, cylinders, or air passages. Never use benzene, kerosene, or other light oils to clean these parts. These oils vaporize easily and will form a highly explosive mixture under compression.

Turn off the motor before making adjustments and repairs on an air compressor.

Before working on or removing any part of a compressor make certain that the compressor is secured and cannot be started automatically or by accident, that air pressure in the compressor is completely relieved, and that all valves between the compressor and receivers are closed.

POWER EARTH AUGERS

An earth auger is used to dig holes for placing posts, poles, and explosives charges. It is also used to remove soils for testing. Among other things, the earth auger is very useful in subsurface soil explorations for boring holes up to 20 inches in diameter and up to 9 feet in depth. The power earth auger (fig. 4-24) is a self-contained, hydraulically operated and positioned earth boring machine. The boring assembly can be operated from vertically downward to 45 degrees from vertical. The power earth auger is normally

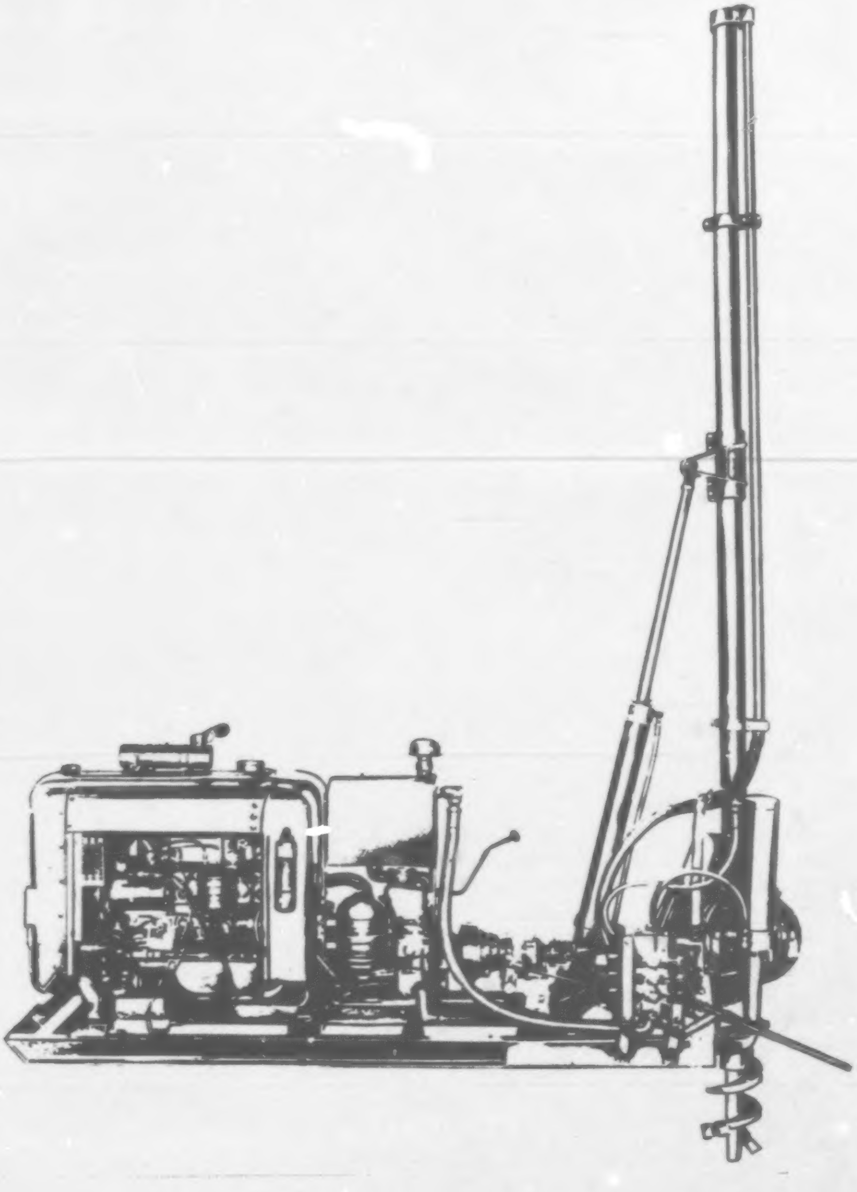


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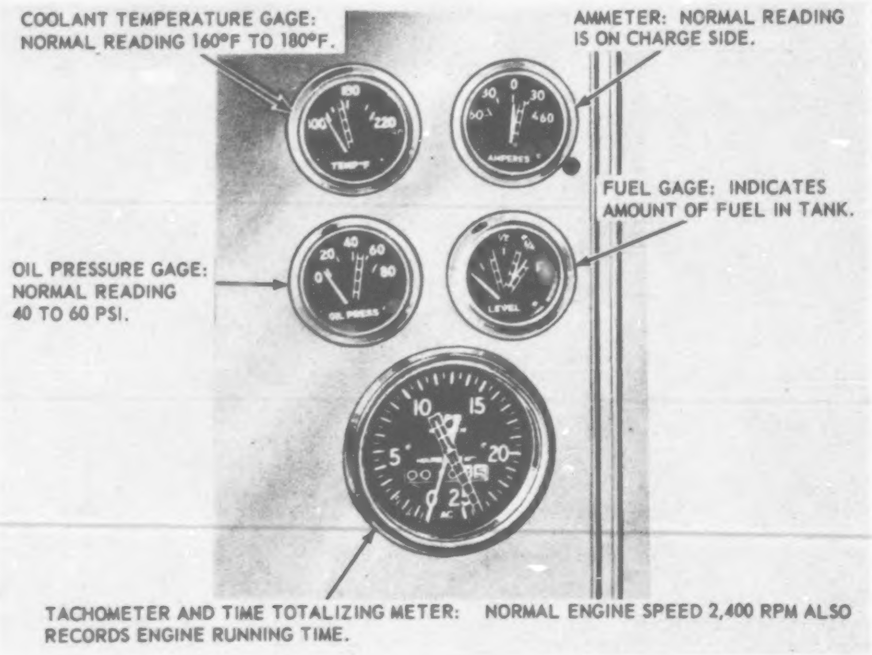
Figure 4-24.—Power earth auger.


COOLANT TEMPERATURE GAGE: NORMAL READING 160°F TO 180°F.

AMMETER: NORMAL READING IS ON CHARGE SIDE.

FUEL GAGE: INDICATES AMOUNT OF FUEL IN TANK.

OIL PRESSURE GAGE: NORMAL READING 40 TO 60 PSI.

TACHOMETER AND TIME TOTALIZING METER: NORMAL ENGINE SPEED 2,400 RPM ALSO RECORDS ENGINE RUNNING TIME.

115.485

Figure 4-25.—Instruments, power earth auger.

mounted on the bed of a truck to increase down pressure and aid in transporting.

The auger, at full speed in fourth gear, will rotate at less than 150 rpm, or in low gear at not more than 40 rpm. The auger hydraulic valve levers are placed so that you can observe the boring operations and the engine instruments at the same time.

The earth auger is usually driven by a gasoline engine. The auger assembly consists of the auger, kelly bar, final drive assembly, and right-angle drive assembly. Operation of the boring assembly is controlled by the auger clutch which engages or disengages the kelly bar.

OPERATION OF POWER EARTH AUGERS

To give you some idea as to the operation of a power earth auger, information is given below on the Texoma Enterprise's earth auger, Jaques model TJ 254. Figures 4-25 and 4-26 show the instruments and controls of this earth auger. Bear in mind that the procedure of operation may vary from one earth auger to another, so make it a practice to check the manufacturer's manual for the recommended procedure for the auger to be used.

Starting the Auger Engine

There are certain steps you must take in starting the auger. After performing the routine prestart checks of the engine crankcase oil level, transmission oil level, fuel supply, battery water level, coolant level, and hydraulic oil level, be sure that the proper amount of lubricant, water, and electrolyte is added, as required, to bring the specific unit to the proper level or full mark. Place all controls in neutral position and then open the fuel shutoff valve and the hydraulic oil shutoff valve. By following the step-by-step procedures given in figure 4-27, you should have no difficulty starting the auger engine.

Steps for Auger Operation

Follow the procedures below to place the power earth auger in motion after the engine has been started:

1. Disengage the engine clutch and shift the transmission into fourth gear.

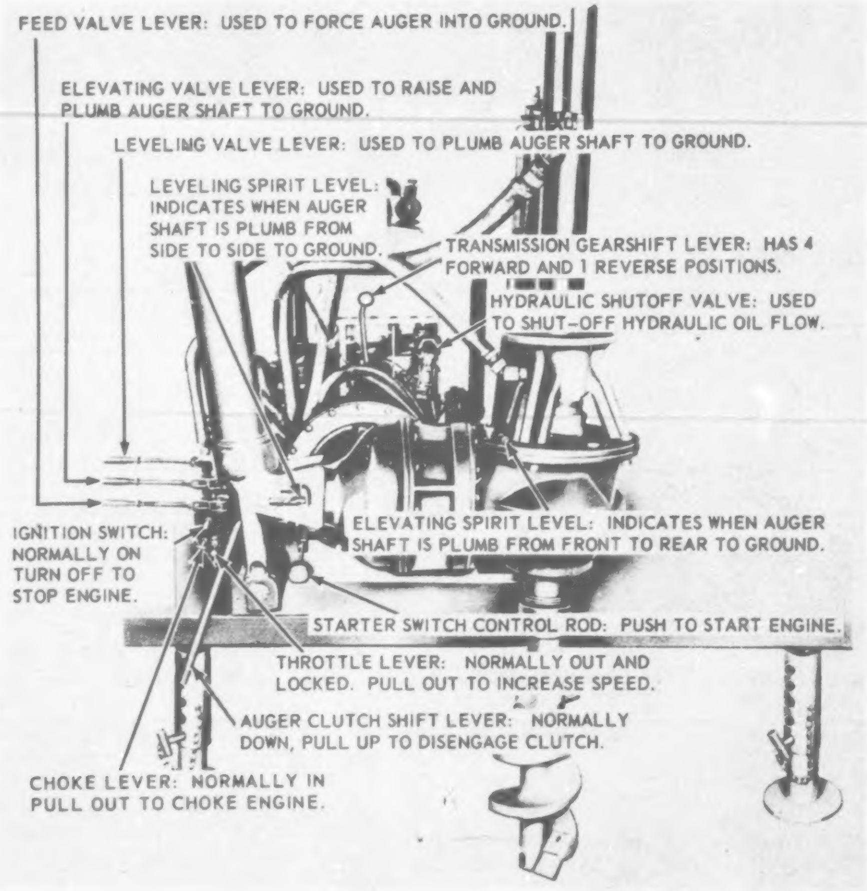
2. Engage the engine clutch and run the engine at idle speed.

3. Pull the elevating valve lever to elevate the auger shaft into the vertical position and plumb as indicated by the elevating spirit level.

4. Engage the auger clutch by pressing down on the auger clutch shift lever and allow the auger shaft to rotate for 5 minutes.

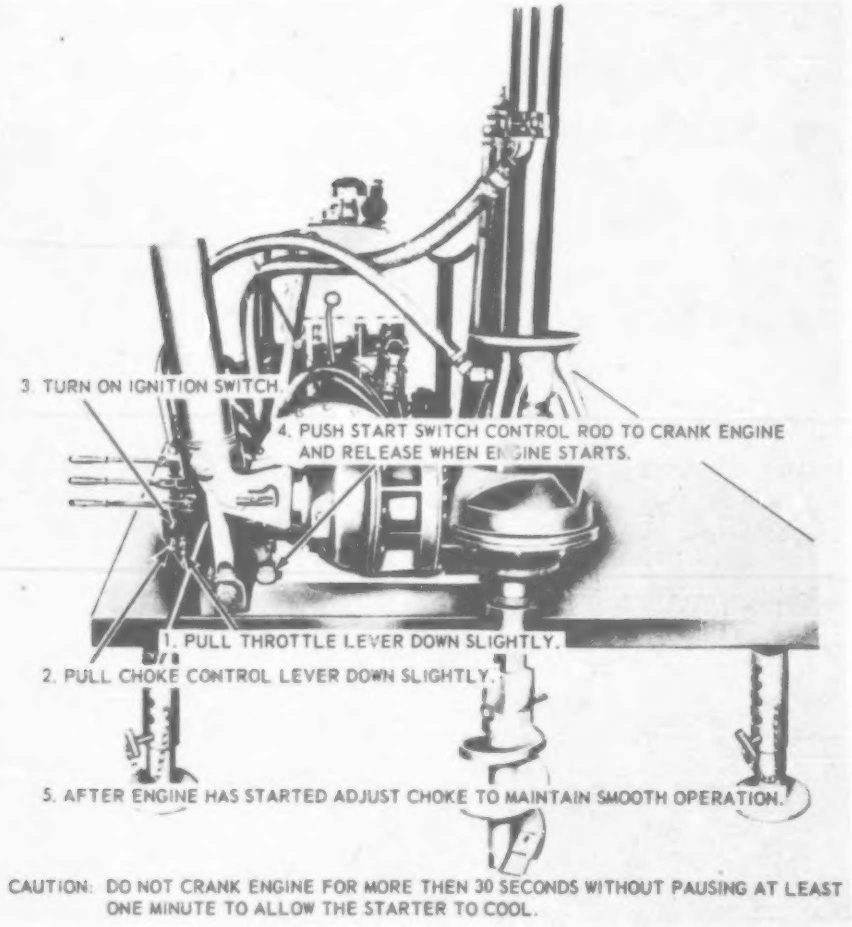
NOTE: Do not run the engine faster than idle until the auger gears are thoroughly warmed up.

5. After the auger has been warmed up, disengage the auger clutch.


FEED VALVE LEVER: USED TO FORCE AUGER INTO GROUND.
ELEVATING VALVE LEVER: USED TO RAISE AND PLUMB AUGER SHAFT TO GROUND.
LEVELING VALVE LEVER: USED TO PLUMB AUGER SHAFT TO GROUND.
LEVELING SPIRIT LEVEL: INDICATES WHEN AUGER SHAFT IS PLUMB FROM SIDE TO SIDE TO GROUND.
TRANSMISSION GEARSHIFT LEVER: HAS 4 FORWARD AND 1 REVERSE POSITIONS.
HYDRAULIC SHUTOFF VALVE: USED TO SHUT-OFF HYDRAULIC OIL FLOW.
IGNITION SWITCH: NORMALLY ON TURN OFF TO STOP ENGINE.
ELEVATING SPIRIT LEVEL: INDICATES WHEN AUGER SHAFT IS PLUMB FROM FRONT TO REAR TO GROUND.
STARTER SWITCH CONTROL ROD: PUSH TO START ENGINE.
THROTTLE LEVER: NORMALLY OUT AND LOCKED. PULL OUT TO INCREASE SPEED.
AUGER CLUTCH SHIFT LEVER: NORMALLY DOWN, PULL UP TO DISENGAGE CLUTCH.
CHOKE LEVER: NORMALLY IN PULL OUT TO CHOKE ENGINE.

115.486

Figure 4-26.—Controls, power earth auger.



3. TURN ON IGNITION SWITCH.

4. PUSH START SWITCH CONTROL ROD TO CRANK ENGINE AND RELEASE WHEN ENGINE STARTS.

1. PULL THROTTLE LEVER DOWN SLIGHTLY.

2. PULL CHOKE CONTROL LEVER DOWN SLIGHTLY.

5. AFTER ENGINE HAS STARTED ADJUST CHOKE TO MAINTAIN SMOOTH OPERATION.

CAUTION: DO NOT CRANK ENGINE FOR MORE THEN 30 SECONDS WITHOUT PAUSING AT LEAST ONE MINUTE TO ALLOW THE STARTER TO COOL.

115.487

Figure 4-27.—Starting the auger engine.

Stopping the Auger Engine

To stop the auger engine, observe the steps given in figure 4-28 after disengaging the engine clutch and shifting the transmission into neutral.

OPERATING TECHNIQUES

Under ordinary circumstances an auger will be operated as described below. Figure 4-29 shows the auger controls and how to position the auger with these controls. With the LEVELING VALVE LEVER, the auger shaft can be tilted to the right or left as indicated in view A. With the ELEVATING VALVE LEVER, the auger shaft can be raised or lowered for transporting, as shown in view B of the illustration. The LEVELING SPIRIT LEVEL is used to plumb the auger shaft.

After the auger shaft has been placed in the desired drilling position you are ready to begin drilling operations. This is done by engaging the auger CLUTCH LEVER, pulling back on the THROTTLE LEVER to increase engine speed, and then pushing forward on the FEED VALVE LEVER to lower the auger into the ground as shown in view C, figure 4-29.

CAUTION: Do not overspeed the auger. Run the engine at slow speed until the texture of the material can be determined.

When the auger is deep enough in the ground to be loaded with dirt, disengage the auger CLUTCH LEVER and pull back on the FEED VALVE LEVER to raise the auger from the hole. After the auger has cleared the hole, engage the auger CLUTCH LEVER (fig. 4-29) to rotate the auger and to clear the unit of dirt. Remember, as you raise the auger, push the hand THROTTLE forward to lower engine speed.

Repeat the steps above until the hole being drilled is at the desired depth.

SECURING A TRUCK-MOUNTED POWER EARTH AUGER

When mounted on a truck for portable use, a power earth auger should be secured in the following manner: Position the auger for traveling and stop the auger engine. Be sure to close the fuel shutoff valve and the hydraulic oil shutoff valve. Drive the truck to the designated securing area, and position the auger in a safe manner. After the truck has stopped, disengage the engine clutch, put the main transmission shaft lever in neutral, engage the truck parking brake, and turn the ignition off. Secure all doors and windows before leaving the truck.

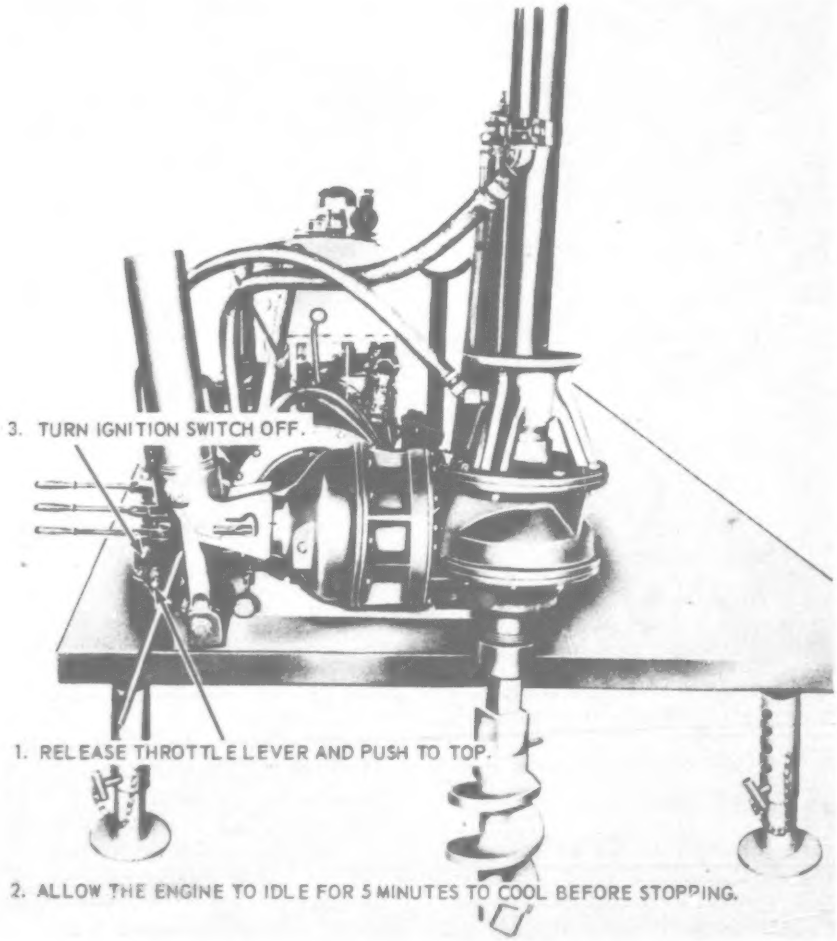

3. TURN IGNITION SWITCH OFF.
1. RELEASE THROTTLE LEVER AND PUSH TO TOP.
2. ALLOW THE ENGINE TO IDLE FOR 5 MINUTES TO COOL BEFORE STOPPING.

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Figure 4-28.—Stopping the auger engine.

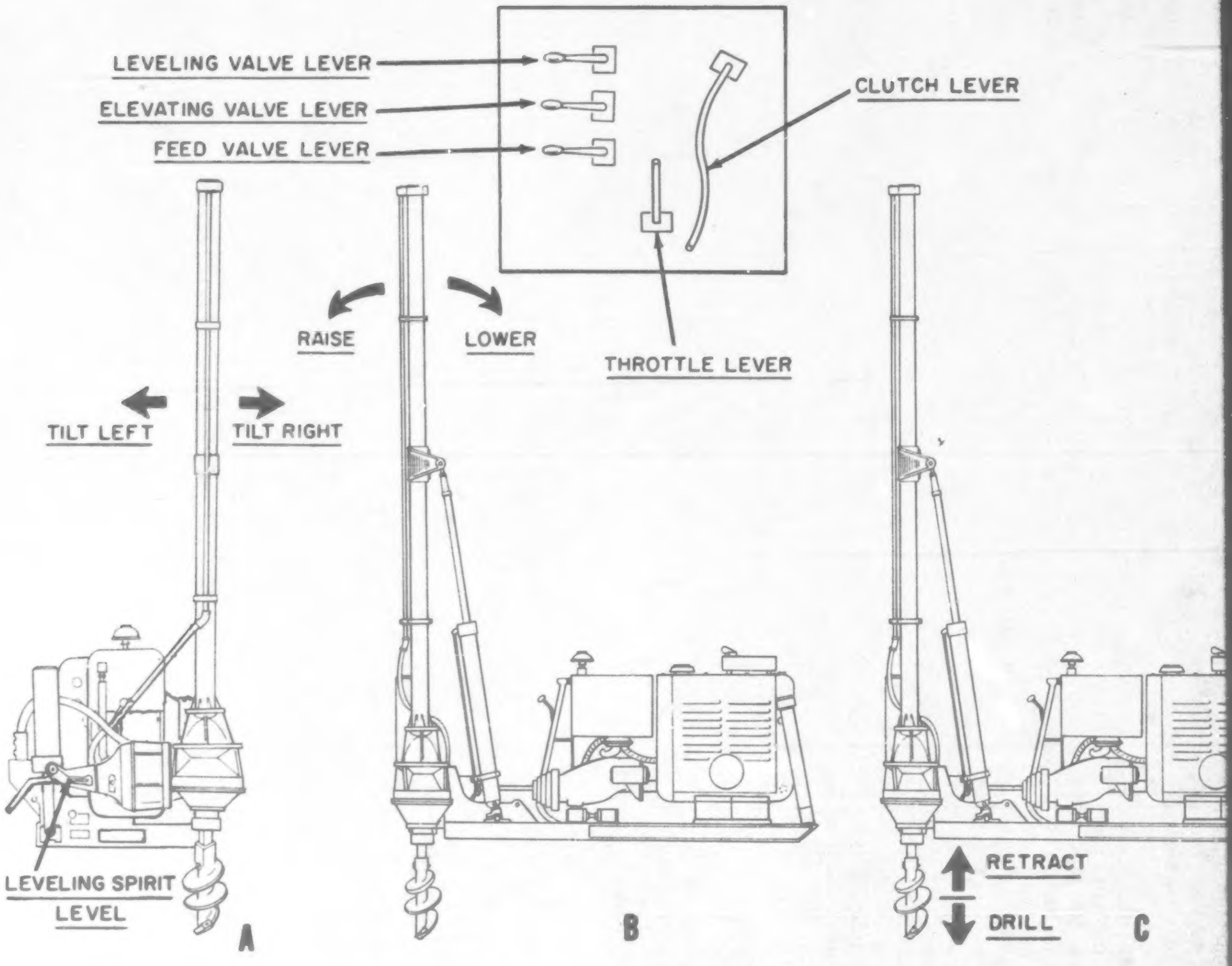
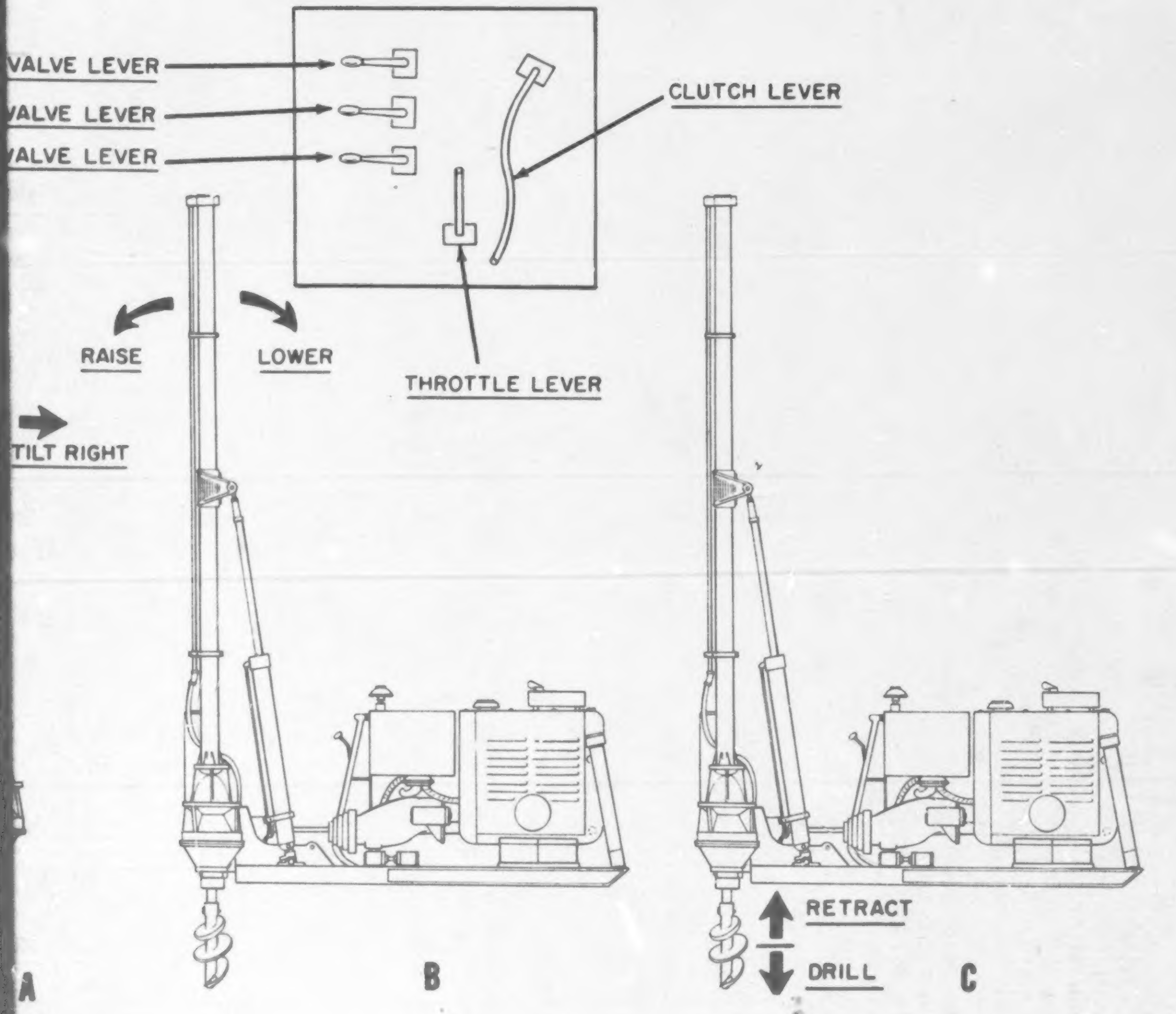

LEVELING VALVE LEVER
ELEVATING VALVE LEVER
FEED VALVE LEVER
CLUTCH LEVER
THROTTLE LEVER
RAISE
LOWER
TILT LEFT
TILT RIGHT
LEVELING SPIRIT LEVEL
RETRACT
DRILL
A
B
C

Figure 4-29.—Using auger controls for positioning of auger.


VALVE LEVER
VALVE LEVER
ALVE LEVER
CLUTCH LEVER
RAISE
LOWER
THROTTLE LEVER
TILT RIGHT
A
B
RETRACT
DRILL
C

115.489

Figure 4-29.—Using auger controls for positioning of auger.

AUGER CARE AND MAINTENANCE

The manufacturer's maintenance manuals contain complete instructions on the care and maintenance, including lubrication requirements, for the auger. Whatever the type of auger you are operating, be sure to:

1. Check the auger daily when in use for loose nuts and bolts and for worn parts.
2. Check the fuel, lube oil, battery, coolant levels, and hydraulic oil.
3. Fill the fuel tank at the end of each workday.
4. Keep the auger free of dirt and mud.
5. When you leave the auger for an extended period, disengage the auger clutch lever, as well as the engine clutch lever, and place the engine transmission in neutral.

Proper lubrication of an auger will prolong its life. Fuels, oils, and greases should be of a good quality and kept free of dirt, water, and other foreign matter.

AUGER SAFETY

General safety precautions for power earth augers are as follows:

1. Don't leave the auger unattended when drilling.
2. Don't engage the engine or auger clutch lever too fast. Engage these levers gradually to prevent damage to the gear cases and other moving parts.
3. Don't fill the fuel tank with the engine running.
4. NEVER attempt to remove an object from the auger while the auger is running.
5. Don't let anyone stand close to the rotating auger.
6. Align the auger with the hole being drilled.
7. Do not feed the auger too quickly during drilling.
8. Be sure the rig is on firm ground. Use support jacks when operating the auger in hardpan or rocky soil, which will cause the auger to bounce.
9. Use supporting jacks when operating the auger in thick clay or mud-like material, which will cause suction when removing the auger from the holes.
10. Wear protective headgear (safety hat) and safety shoes when operating the auger.
11. Be sure to secure all machinery while repairs, adjustments, or manual lubrications are being made.
12. Cover holes in which poles or other construction materials have not been placed. Covers must be able to support men or equipment safely.

CHAPTER 5

TEST EQUIPMENT

As a Construction Electrician, you will be required to place new electrical equipment into operation, repair defective equipment, and perform routine preventive maintenance. To help you accomplish these jobs, many types of test equipment are available. Some of these may appear to be complex. When analyzed, however, their theories and techniques of operation may be reduced to simple basic circuits and procedures. Electrical theory underlying the operation of some basic test instruments is covered in detail in chapter 15 of Basic Electricity, NAVPERS 10086-B. A good grasp of this material will help you to understand not only how the instruments are designed to work, but also the importance of applying theoretical analysis to problem solving.

This chapter describes test procedures and equipment used for investigating a variety of difficulties. You should be able to repair vital equipment when you follow correct test procedures and the manufacturer's instructions.

The purpose of these instruments is to test and measure accurately certain circuit values or to determine the operating condition of the electrical circuits. Instrument accuracy depends on its design and how it is treated.

The operating energies involved in electrical measuring instruments are extremely small. The instruments themselves are necessarily of delicate construction. Special precautions must be taken to obtain accurate results and to avoid injury to the operator by mechanical shock, exposure to strong magnetic fields, and excessive flow. One of your major responsibilities is to take care of any instruments assigned to you. Instructions and wiring diagrams are furnished with instruments. Such instructions are either attached to the instrument case or cover, or are given in separate instruction books. These should be consulted freely for specific instructions and precautfons.

BASIC MEASURING INSTRUMENT PRECAUTIONS

When using measuring instruments, you must observe certain precautions. For example, it is especially important to be careful in using an ammeter because of its low internal resistance. If mistakenly placed across a voltage source, the meter can be damaged. Always break the circuit and CONNECT AN AMMETER IN SERIES, with one meter lead going to each point of the circuit break to measure an unknown quantity. Be sure to deenergize the circuit before making or breaking the connections.

When using either ammeters or voltmeters, ALWAYS start at the HIGHEST meter range. Then drop down to a lower scale range if necessary. This practice protects the meter from injury if an attempt is made to read a high value in a low range. Damage to instruments can also be minimized if you form the habit of placing the range selector switch in the highest range position after you have finished using the instrument.

OBSERVE POLARITY on all direct current measurements. Take care to connect the positive terminal of the source to the positive terminal of the meter, and the negative terminal of the source to the negative terminal of the meter. This ensures that the meter polarity matches the polarity of the circuit in which the meter is placed.

Be careful to avoid dropping a meter or subjecting it to excessive mechanical shock. Such treatment may damage the delicate mechanism or cause the permanent magnet to lose some of its magnetism.

Care must be taken to avoid connecting the ohmmeter across circuits in which a voltage exists, since such connection can result in damage to the instrument. TO ENSURE THE REMOVAL OF ALL VOLTAGE TO THE EQUIPMENT UNDER TEST, DISCONNECT THE SOURCE OF INPUT VOLTAGE BY REMOVING

THE POWER PLUG. Furthermore, ALL CAPACITORS MUST BE DISCHARGED before the ohmmeter prods are connected in the circuit. Charges remaining on capacitors after the applied voltage has been removed can damage the instrument severely.

Always turn ohmmeters OFF when finished. This will avoid discharge of the internal battery if the test leads are shorted inadvertently.

It is important that you remember to USE A LOW VOLTAGE MEGGER TO TEST LOW VOLTAGE INSULATION. Application of high voltage may initiate insulation breakdown. LOW VOLTAGE MEGGERS should not be used to test high voltage insulation because an inaccurate reading may result from the comparatively small output voltages available from this instrument. Be careful, whether using high or low range meggers. Dangerous voltages exist at meter terminals and leads.

BASIC TEST EQUIPMENT

As a CE, you will use various types of test equipment. Some of the basic types of test equipment with which you should be familiar are described in the following paragraphs.

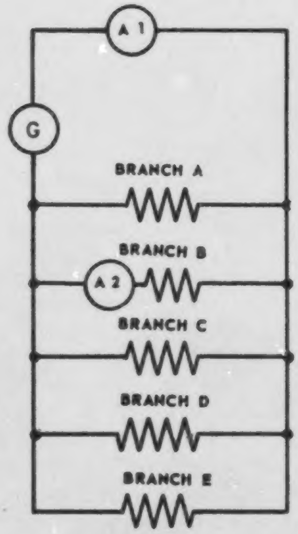


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Figure 5-1.—Metering current in an entire circuit and in one branch circuit.

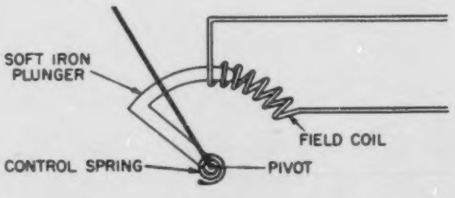

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Figure 5-2.—Schematic of a magnetic-vane attraction-type ammeter.

AMMETERS

You can use an ammeter to measure total current through a circuit, or you can use it to measure current through only a part of the circuit. Figure 5-1 illustrates both methods of measurement. In the figure the symbol A1 indicates an ammeter which is measuring the total current through branch circuits A, B, C, D, and E. The symbol A2 indicates an ammeter which is measuring the current through branch circuit B only.

Because the function of an ammeter is to measure current, it must always be connected in series with the line, and with the load on the line. It must never be subjected to a current higher than the rating on the meter.

In the type of ammeter used at advanced bases, the coil through which the measuring current flows is fixed to the instrument frame. The magnet is a movable vane of iron or of special alloy, as indicated in figure 5-2. Magnetism induced in the iron by the current in the field coil always has the same polarity as that of the coil, when alternating current flows in the coil. Therefore, when the current reverses in the coil, the polarity of the magnetism induced in the moving iron also reverses.

The instrument is calibrated in amperes, and rated according to its maximum current-carrying capacity. Because of the fixed relationship in polarity between field flux and moving vane flux, the instrument could be calibrated for either alternating or direct current. In the latter case, however, the meter could not indicate the polarity of the current.

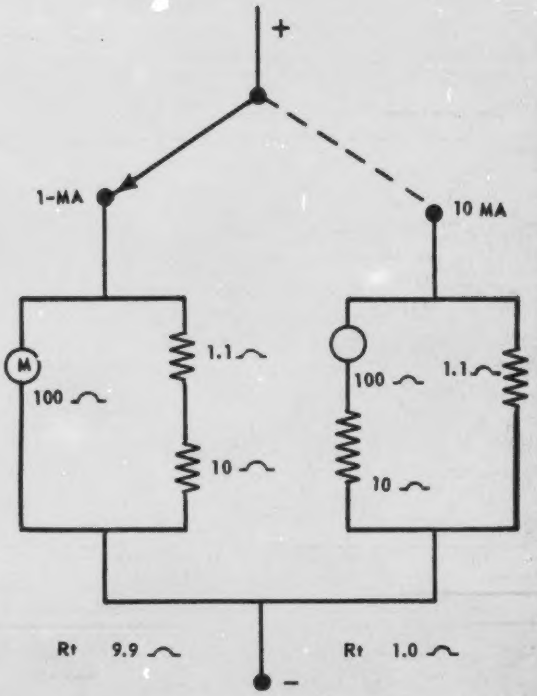
The field coil must supply all the energy necessary to operate the meter movement. Any meter of a given rating, operating on the moving-vane principle, requires more power than a moving-coil meter of the same rating. The moving-vane type can carry a higher operating current, because the current flows through a stationary circuit.

However, there are certain limitations on current ranges. For example, the size of the instrument places the primary limitation on maximum rating. The maximum amount of heat that can be dissipated is dependent upon the size of the meter. The size of the connecting terminals also depends on the size of the meter.

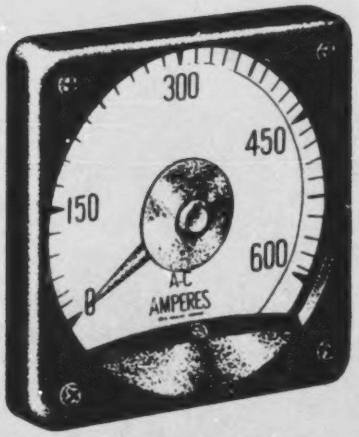
An additional limitation exists in the so-called MULTIRANGE ammeters (those equipped with one or more shunts, as explained later), because of the requirements of the range-switching mechanism. The particular consideration here is to keep the size of the mechanism switch within practical limits. A switch with the necessary low-contact resistance for very high currents would probably be too large for the meter case.

Some examples of maximum currents that can be measured by various types of ammeters are as follows: Switchboard instruments (fig. 5-3) usually are capable of indicating current up to 600 amp. Large portable ammeters may be rated up to 100 amp. Multirange ammeters are usually rated not more than 60 amp.

Figure 5-4 shows a schematic of an ammeter with two shunts (shunts for instruments are explained in Basic Electricity). The shunts can be arranged to make up two ranges, depending upon the value of the current that is being measured. The shunts in figure 5-4 are internal—that is, installed inside the meter case. They are fixed shunts, meaning that when the meter is installed in a circuit, the shunts become part of the circuit.



73.40
Figure 5-4.—Multiple-shunt ammeter.



73.39X
Figure 5-3.—Typical switchboard ammeter.

External shunts are installed on the outside of a meter case, or on the back of a switchboard. They can be changed for the purpose of increasing the range of the meter. Although you are not supposed to make adjustments on meters, there may be an occasion when you have no instrument available that suits a special need, and will have to improvise from what is at hand.

The shunting method about to be described is not really satisfactory for ammeters operating on the fixed-coil moving-vane principle. A shunt is entirely satisfactory on a moving-coil instrument, to extend the range upward. A moving-iron element, however, is much less sensitive than a moving coil, and would require a greater voltage drop across the shunt.

Greater voltage drop causes greater heating in the shunt. Greater heating must be offset by larger size, to safely dissipate the heat. At the points where the instrument leads are connected to the instrument and to the shunt, contact resistance could cause a drop in voltage large enough to affect the reading. Every time the instrument is used, contact resistance could be different, with consequent differences in the effect on the reading. It would therefore be difficult to correct for the error in reading.

Another difficulty in applying a shunt to the a-c ammeter is caused by a difference in inductive reactance between instrument coil and shunt. With changes in frequency, the impedance of the coil may vary. Therefore, a shunted a-c instrument may be relied on to read accurately only at the calibrating frequency.

Most multirange a-c ammeters have two scales, one of which indicates values which are exactly double the corresponding values on the other. The method used to provide these two ranges on the same instrument is as follows: The field coil, instead of being wound with a single conductor, is wound with two parallel conductors. Thus the winding is really two equal sections, each of which bears an identical relation to all other parts of the instrument.

The ends of the two sections are usually brought to separate terminals. In some instruments, they may be connected to a switch built into the instrument. Either arrangement makes it possible to connect the two windings in series or in parallel, as desired.

When it is desired to use the low-current range, the windings are connected in series. To use the high-current range, parallel connection of the windings is required. On the ammeters that you will use, choosing the current range will probably be done by a selection of terminals.

If you must connect an ammeter into a circuit with an unknown current value, select the highest possible range, and work down gradually until you reach the proper range. It is not wise to accept a range if the reading is at the highest point on the scale. You will have more accurate readings if the pointer comes to rest near the center.

In this connection you should be warned not to use an ammeter whose highest calibrated value is the same as the current expected in the circuit into which it is to be connected. For example, if you are going to meter a current you believe to be 5 amp, use a 10-amp ammeter rather than a 5-amp ammeter.

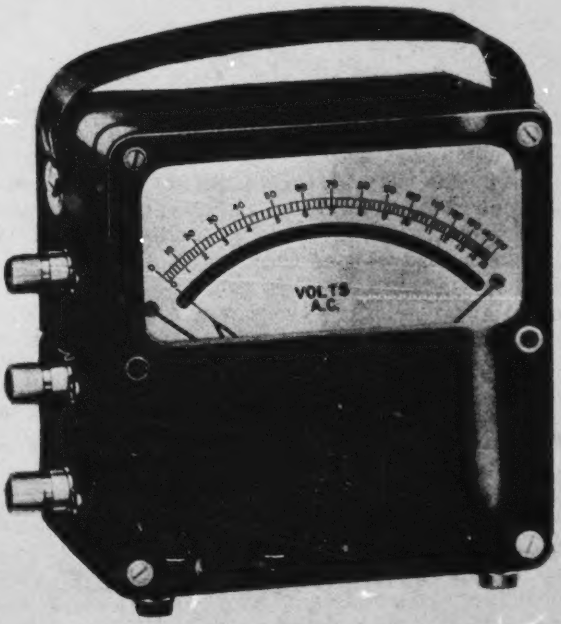
Some d-c ammeters have a scale in which zero is centered on the dial instead of being located at the far left as in figure 5-3. On this type of instrument current can be read in either direction—that is, either a charging current or a discharging current. Such an ammeter is used in shop work, or any place where it is necessary to read the current in a storage battery circuit.

Here are some FACTS you MUST know about ammeters:

1. Always connect an ammeter in series with the line and with the load. If it were connected in parallel, full line voltage would send a tremendous surge of current through the meter movement, and this would burn out the delicate coil.

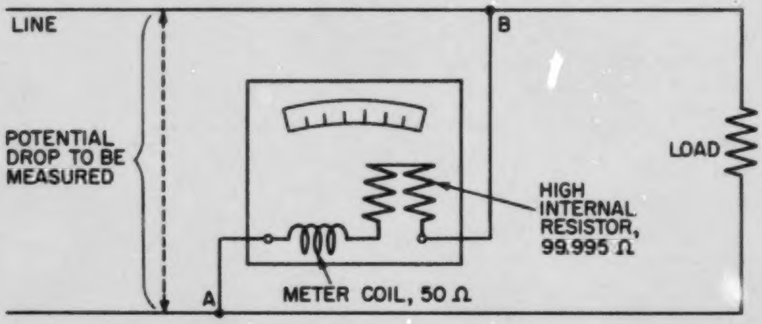
2. Never connect an ammeter to a circuit in which the current is equal to, or higher than, the rating of the meter.

3. If the current to be measured is of unknown value, start with the highest current range available, and use successively lower ranges until you reach the one that gives the proper reading.



5.102

Figure 5-5.—Voltmeter.


LINE
B
POTENTIAL DROP TO BE MEASURED
LOAD
HIGH INTERNAL RESISTOR, 99.995 Ω
A
METER COIL, 50 Ω

73.41

Figure 5-6.—Schematic of a voltmeter.

4. Be careful, when connecting an ammeter into a circuit, not to connect it so you get a reverse polarity.

VOLTMETERS

A voltmeter is a device for measuring the voltage in a circuit—that is, the difference in electrical pressure between two selected points.

Figure 5-5 shows a common type of voltmeter. Note the double scale, a feature which will be explained later in this section.

Voltmeters must always be connected IN PARALLEL with the circuit. If the resistance were constant, and if its relation to the voltage were such that only a very small current flowed through the circuit, an ammeter could be used to read voltage as well as amperage. Of course, the instrument dial would have to be calibrated for voltage as well as amperage.

Resistance, in fact, is seldom constant. However, the basic direct relationship between voltage, resistance, and current (which is expressed in Ohm's law) can be utilized. This is done by adding a fixed resistance (other than that of the coil) to the meter movement, and calibrating the scale in volts.

Both a-c and d-c voltmeters, then, determine voltage by actually measuring the current a voltage is able to force through a high resistance connected IN SERIES WITH THE METER MOVEMENT. It follows that the construction and operating principles of the voltmeter are similar to those of the ammeter. A schematic of a voltmeter is shown in figure 5-6. You can see that the instrument has a high internal fixed resistance in series with the coil of the meter, with the meter itself connected across the line.

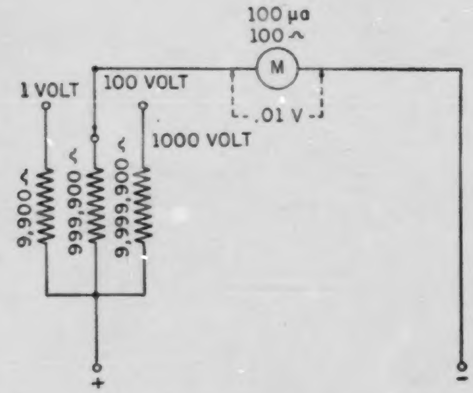
Because the meter is connected across the line, changes in the load have no effect on the reading. However, any change in the voltage across A and B will cause a corresponding change in the reading.

The high resistance built into a voltmeter gives it a degree of protection, so that the instrument is more rugged than an ammeter. Connecting an ammeter across the line will cause the meter to burn out almost immediately. However, if a voltmeter is mistakenly connected in series instead of parallel, the movement will not be damaged, unless the voltage is much higher than the rating of the instrument.

More than one fixed resistor may be connected inside the voltmeter, and the dial calibrated to show a scale for each resistor. The voltmeter shown in figure 5-5 has two scales, indicating two internal resistors. Figure 5-7 is a schematic of a voltmeter with three fixed resistors and therefore three ranges.

In multirange voltmeters, the meter movement is designed to operate up to full scale on the lowest range. Higher ranges are obtained by selecting the additional resistor (or resistors) of the required value. But because a low-rated voltmeter draws more current than a higher-rated voltmeter, combining a lower-range instrument with a higher-range one calls for higher power consumption. Therefore, any multirange voltmeter must be so designed as to be capable of dissipating the additional heat.

There is always the possibility of reading errors caused by high temperatures, and it has been found necessary to impose a limit on the



73.42

Figure 5-7.—Multirange voltmeter.

number of ranges combined in a single instrument.

Most voltmeters are calibrated to show one of the following ranges: 0 to 10 volts; 0 to 100 volts; 0 to 300 volts; 0 to 500 volts. There are also instruments that are calibrated in millivolts, or even microvolts for measuring very small voltages; others are calibrated in kilovolts for measuring very high voltages.

The correct voltage range to use can be readily chosen when approximate line voltage is known. If you do not know the approximate voltage in the circuit to be tested, always select the highest range available. You can then choose lower ranges, in successive tests, until a suitable reading is obtained.

In most cases, you will be working with voltages of less than 600 volts. If an occasion arises when you have to measure a higher voltage—certainly when you must measure a voltage as high as 750 volts—it may be necessary to adapt an available meter to accommodate this higher load.

This can be done by adding an external resistor, commonly called a multiplier. This additional resistor, if absolutely required, should be taken care of by a trained repairman, or by an experienced senior petty officer.

The following points are the ones which you must always bear in mind when using a voltmeter.

1. Select a voltmeter with a range suitable for measuring the voltage of the circuit to be tested.

2. If the approximate voltage of the circuit to be tested is unknown, start with the highest voltage range, and use successively lower ranges until you obtain a suitable reading.

3. Connect the instrument IN PARALLEL with the line and with the load.

4. In a direct-current circuit, take care to connect the positive terminal of the meter to the positive terminal of the source, and the negative terminal of the meter to the negative terminal of the source. This ensures that meter polarity matches the polarity of the circuit in which the meter is placed.

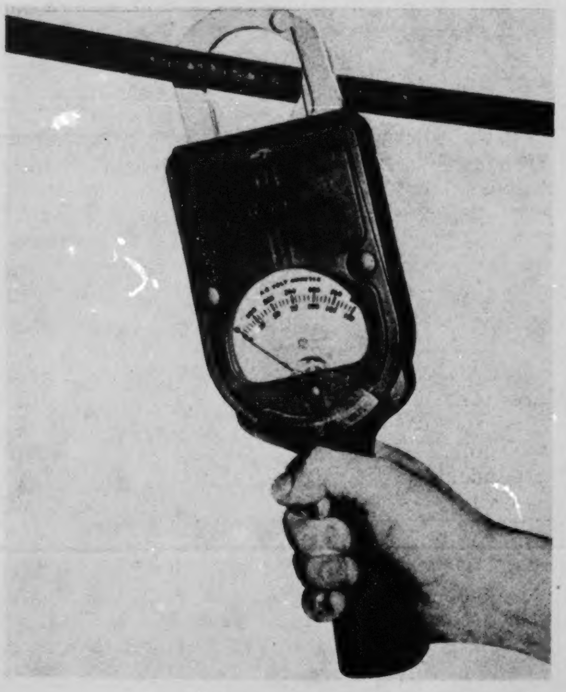
CLAMP-ON-VOLTAMMETERS

It is possible to measure alternating voltage and current, without breaking into a circuit, by the use of a clamp-on VOLTAMMETER. The instrument can be clamped around a conductor, of either bare or insulated wire, and it will give the effective reading of alternating current as soon as you move a selector switch to the appropriate scale. To read a-c voltage you must set the selector switch at the highest scale, connect the leads from the terminals of the instrument to the circuit being tested, and then move the selector switch to the proper voltage scale.

CAUTION: Be sure circuit is deenergized before making the connection to check the voltage reading, if there is no insulation on the test clips.

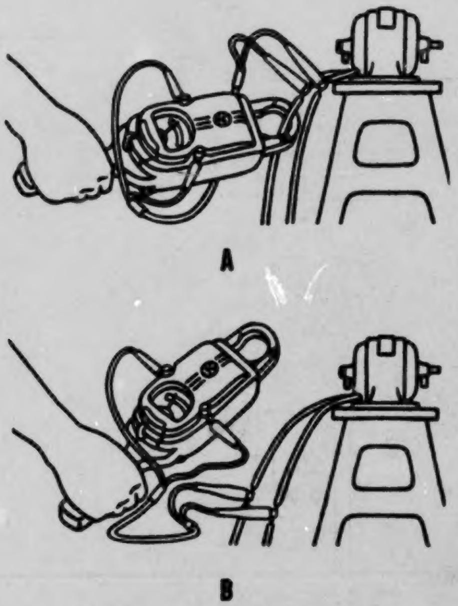
The selector switch provides a choice of several current ranges and voltage ranges. For example, current ranges might be as follows: from 0 to 15, from 1 to 60, from 0 to 150, or from 1 to 600 amp; voltage ranges might be from 1 to 150 or from 1 to 600 volts. These are the ranges on the voltammeter shown in figure 5-8. This instrument has a 6-position selector switch, shown just above the thumb in the figure. There are 4 positions for selecting amps, 2 for selecting volts.

Because the switch is mounted just above the handle of the voltammeter, it can be easily manipulated by the hand with which you are holding the instrument. You can measure both current and voltage with the same hookup, but not at the same time. Figure 5-9, view A, illustrates reading both current and voltage in a single hookup. Figure 5-9, view B, shows how you read voltage only. To read current



73.43X

Figure 5-8.—Clamp-on voltammeter.



73.44

Figure 5-9.—Determining current and voltage in the same hookup. (A) Voltage and amperage. (B) Voltage only.

value, the selector switch must be set at AMPERES; to read voltage it must be set at VOLTS.

To read voltage, you must have the leads connected from the voltage terminals on the meter to the terminals across which the voltage is to be measured. Leaving the voltage leads connected does not affect current reading when the instrument is hooked around the line and the switch is thrown AMPERES.

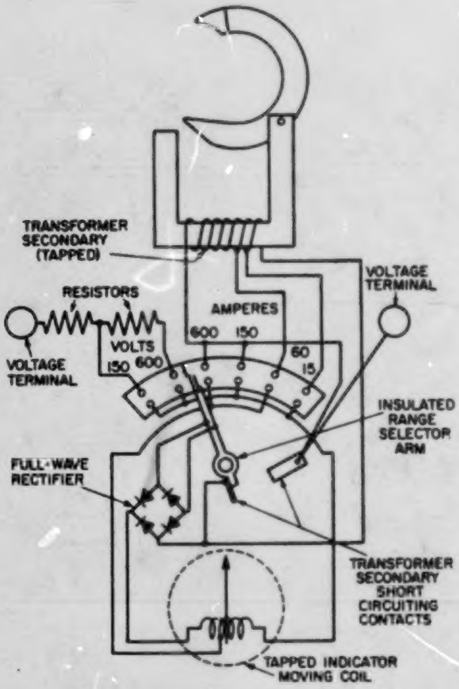
The operating principle of the voltammeter is based on an indicating element which is deflected according to the strength of the magnetic field around a current-carrying conductor. The core is hinged. The dovetail joint that closes around the conductor in the application of the voltammeter provides a complete path for the magnetic circuit. Figure 5-10 shows the internal connections of the voltammeter.

To attach the instrument to a conductor, open the split-core transformer manually, and then place the instrument so that the conductor runs through the dovetail joint. A push on the instrument handle will close the dovetail joint of the core around the conductor.

The position of the conductor has very little effect on the accuracy of the reading. When you are ready to remove the voltammeter, you can open the transformer core by pulling GENTLY on the instrument handle.

The split core is large enough to enclose conductors up to 2 in. in diameter. If you are measuring currents of small value (one or two amp), you may find it advisable to extend the current range to provide a more reliable reading. You can do this by looping the conductor two or three times around the transformer core as shown in figure 5-11. You then divide the reading you get by the number of times you looped the conductor.

When the conductor is not slack enough to permit looping, attachments are available for the same purpose. Even when there is enough slack in the conductor, there is always the risk of breaking or disconnecting it. If you have

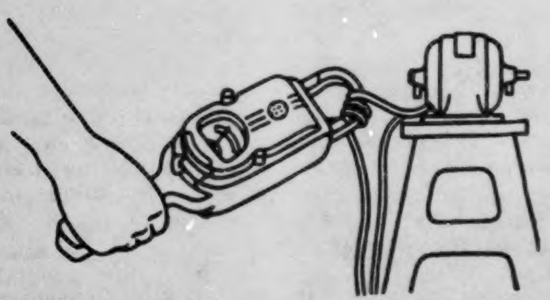

TRANSFORMER SECONDARY (TAPPED)
RESISTORS
AMPERES
600
150
VOLTAGE TERMINAL
VOLTS
150
600
60
15
VOLTAGE TERMINAL
INSULATED RANGE SELECTOR ARM
FULL-WAVE RECTIFIER
TRANSFORMER SECONDARY SHORT CIRCUITING CONTACTS
TAPPED INDICATOR MOVING COIL

73.45X

Figure 5-10.—Internal connections of a clamp-on voltammeter.

the attachment, it is best to use it rather than loop the conductor.

A voltammeter is not as accurate as a switchboard meter. Nevertheless, voltammeters are useful instruments in troubleshooting and maintenance work. Be sure to keep pole surfaces clean, and ascertain that they make good contact. A poor contact will, of course, cause error in the reading.



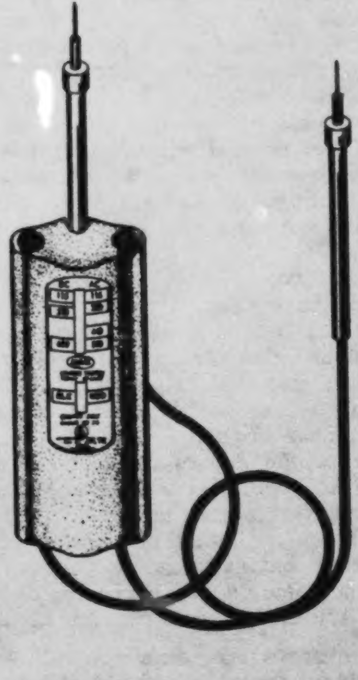
73.46

Figure 5-11.—Extending current range by looping conductor around transformer core.

VOLTAGE TESTER

The solenoid type voltage tester is the most frequently used troubleshooting instrument. Every electrician should understand the use and care of this important tool.

The voltage tester (fig. 5-12) is encased in an insulated housing and can be held in the hand when circuit testing. It has two test probes connected to the meter movements by flexible leads. Inside the housing is a solenoid, a coil having a movable core. When the test probes are placed across terminals having a difference of potential (voltage), current flows in the coil. This resultant current flow, which is dependent upon the amount of difference in potential, sets up a magnetic field surrounding the coil. This magnetic field will pull the movable core into the coil. This magnetic pull works against a return spring. The movable core



73.32

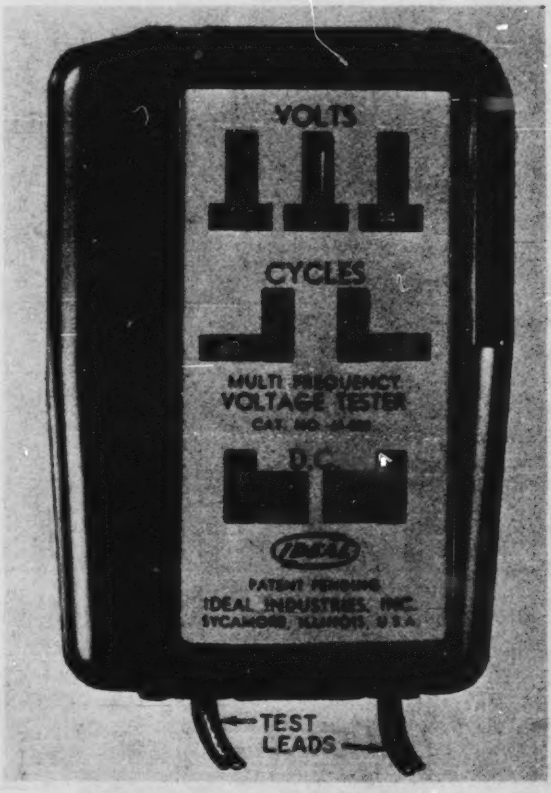
Figure 5-12.—Voltage tester.

has a pointer attached, which is read against a calibrated scale on the face of the housing.

In the center of the tester is a neon glow lamp indicator. The glow lamp is used to indicate if the circuit being tested is a-c or d-c. When the tester is operated on a-c, light is produced only during a portion of each half-cycle, and both electrodes of the glow lamp are alternately surrounded with a glow. When the tester is operated on d-c, light is produced continuously, and only the negative electrode glows. Therefore the tester will indicate polarity on d-c circuits. The test probes are colored red and black and the glow lamp enclosure is labeled red and black. If, while testing a d-c circuit, the electrode of the glow lamp on the side labeled black is glowing, this indicates the black probe of the tester is on the negative side of the circuit; likewise the opposite electrode would glow if the red probe of the tester was on the negative side of the circuit. The solenoid type voltage tester gives an audible hum and noticeable vibration when applied to a source of alternating current.

It is easy to fall into the habit of assuming that normal voltage is present when you feel the vibration and hear the hum. However, these indications only mean that SOME voltage is present. It is necessary to actually READ the scale to determine the amount of voltage because certain defects will cause less than normal voltage. Unless this is done, you may assume that normal voltage is present when the actual voltage is less than normal. Less than normal voltage on certain tests (shown later) is a definite clue to the location of faults.

Another type voltage tester used in the fleet is the multifrequency type shown in figure 5-13. This tester utilizes electronic circuitry and seven neon glow lamps to indicate voltage, frequency, and polarity. This tester may be used on 60- or 400-hertz alternating or direct current. One or more of three lamps light to indicate the amount of voltage, labeled as 110, 220, or 440 volts. At the same time one of the remaining four labeled lamps lights to distinguish the a-c frequency, whether 60 hertz or 400 hertz, or whether having negative polarity applied to either the tester's red probe or its black probe when the tested circuit carries direct current.



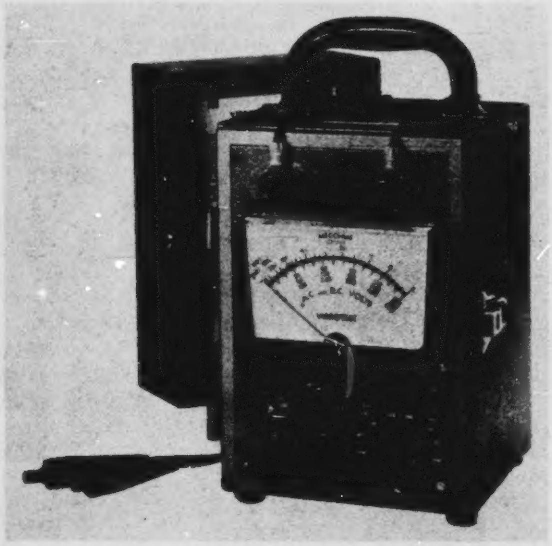
77.240
Figure 5-13.—Multifrequency voltage tester.

Never use a lamp in a "pigtail" lamp holder as a voltage tester. Lamps designed for use on low voltage (120 v) may explode when connected across a higher voltage (440 v). In addition, a lamp would only indicate the presence of voltage, not the amount of voltage. Learn to use and rely on standard test equipment.

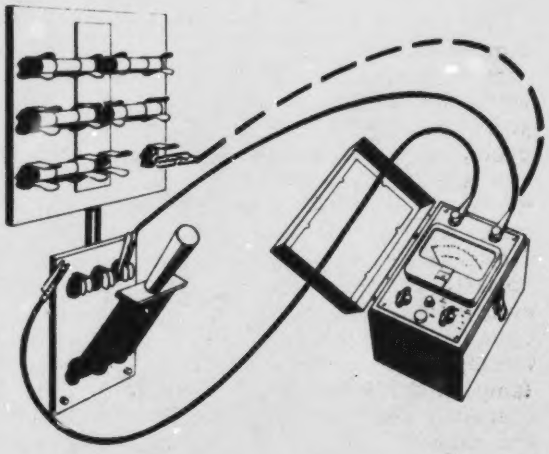
VIBROTEST MEGOHMMETER

Figure 5-14 shows the Vibrotest Megohmmeter. It is used as an insulation measuring instrument primarily, but can also be used as a-c or d-c voltmeter. It is a multipurpose instrument that does not require cranking. A vibrator and transformer develop the voltages required for insulation measurements. Special circuitry reduces surface leakage interference for more accuracy.

Records kept of the various insulation readings taken at the appropriate intervals will help you spot potential insulation breakdowns before



1.55BX
Figure 5-14.—Vibrotest megohmmeter.



73.277X
Figure 5-15.—Testing a distribution panel and its individual circuits.

consequent damage to equipment or personnel occurs.

CAUTION: It is imperative to remember that a high voltage exists across the terminals when testing in the megohm ranges.

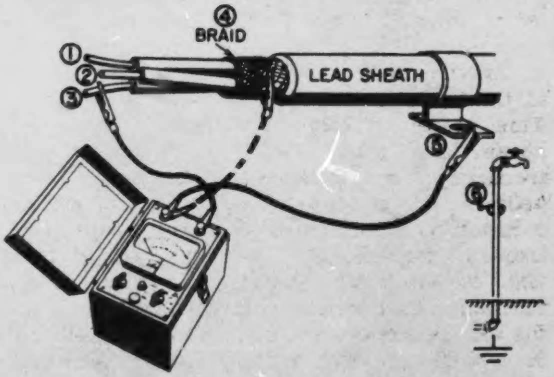
The following descriptions will show you how to determine insulation resistance in a variety of electrical apparatus. BE SURE YOUR EQUIPMENT OR WIRING IS DEENERGIZED.

Cable Insulation Checks

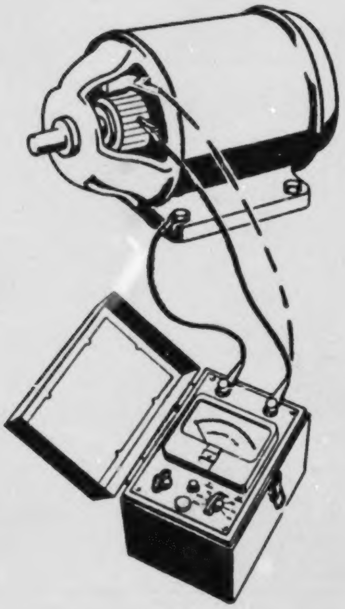
Where you have an ungrounded distribution panel, you can check insulation of the whole wiring system to ground by attaching one test lead to the dead post of the open main power switch and the other lead to a ground (fig. 5-15).

Individual circuits are tested to ground by opening distribution panel switches or fuses and testing each circuit in turn (fig. 5-15, broken lead).

Multiconductor cables may be tested in any of the ways shown in figure 5-16. The drawing



73.278X
Figure 5-16.—Testing multiple conductor cables.



73.279X
Figure 5-17.—Testing direct current motors and generators.

depicts the measurement of insulation resistance between wire (3) and lead sheath (5). Various other measurements can be made such as wire to ground (1, 2, and/or 3 to 6), wire to wire (1, 2, or 3 to any combination of each other), wire to braid (1, 2, or 3 to 4), wire to sheath (1, 2, and/or 3 to 5).

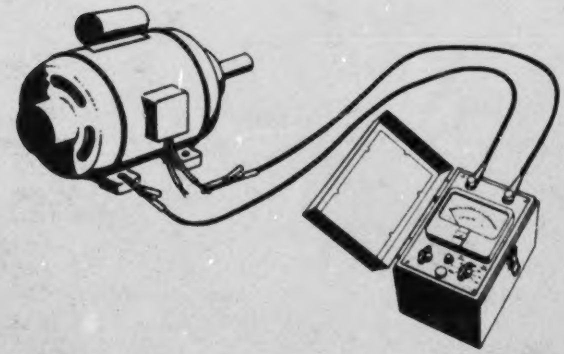
It is good to remember that when you test wiring which is connected to any panel or equipment, there may be appreciable leakage between terminals which will show up in your tests as lowered insulation resistance. If your original record cards were made with panels connected, continue future tests in the same manner.

Checking Motors and Generators

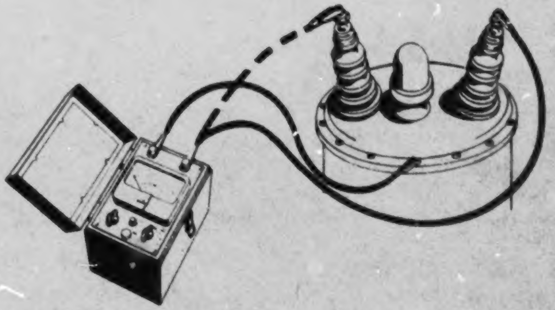
As you know, the bases, frames, and enclosures of electrical equipment must be grounded. The megohmmeter is used to verify that the windings associated with the various components of motors and generators aren't grounded and are properly insulated (figs. 5-17 and 5-18). Before you make any tests, BE SURE TO DISCONNECT THE MOTOR OR GENERATOR FROM THE LOAD AND SOURCE.

Circuit Breaker and Switch Insulation Tests

Figure 5-19 depicts the measurement of insulation resistance between either circuit breaker terminal to ground. This measurement should also be made between terminals. If your breakers are of the oil type, dirty oil may be causing leakage currents through the breaker even when it is open. Dirt or grease in the mounting may be causing leakage in the dry type. Switches and circuit breakers must be COMPLETELY disconnected from line and relay wiring before testing.



73.280X
Figure 5-18.—Testing alternating current motors.



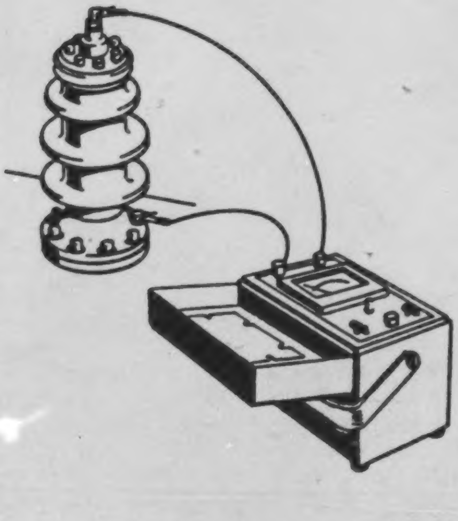
73.281X
Figure 5-19.—Checking circuit breaker insulation resistance.

Insulator Test

Insulators, the "forgotten men" of electrical systems, are subject to several ills that can make them a potential hazard unless they are tested periodically. Breakage is probably the first hazard with insulators. Casually accumulated dirt, grease, or liquids is another. Occasionally, faulty construction makes a brand new insulator a source of danger. To test insulators, connect test leads to each end, then test each end to ground (fig. 5-20).

Capacitor Test

You can use the Vibrotest megohmmeter to check both insulation resistance and approximate capacitance of capacitors. When you connect leads to capacitor terminals, observe polarity carefully. Time your test until the meter pointer stops moving upward, then record insulation resistance at highest reading. Dividing test time, in seconds, by 15 will give you the approximate capacitance, in microfarads, of the capacitor. If one pointer has a tendency to waver toward the high reading, then drop back down the scale. The capacitor may be leaking, and further testing is indicated. Be especially careful to RELEASE PUSHBUTTON before starting to disconnect test leads from capacitors. If you do not give the Vibrotest discharge resistor an opportunity to dissipate the stored potential in the capacitor, you may get a severe shock.



73.282X

Figure 5-20.—Testing insulators.

Transformer Test

Deenergize equipment. Disconnect the leads from both primary and secondary windings. Tests can be made of either the primary or secondary winding individually by connection of the negative lead an associated ground (case, metal mounting, or manmade ground), and the lead from the winding under test to the positive lead. Following tests of each winding, it is a good idea to test insulation resistance between the windings themselves. Connect one test lead to the primary (either lead); and the second test lead to the secondary. All of these tests, under proper identifying labels, should be recorded on a record card.

If you have transformers with multiple-voltage windings, the procedures above should be followed to test all windings to ground, and each winding's resistance value to every other winding.

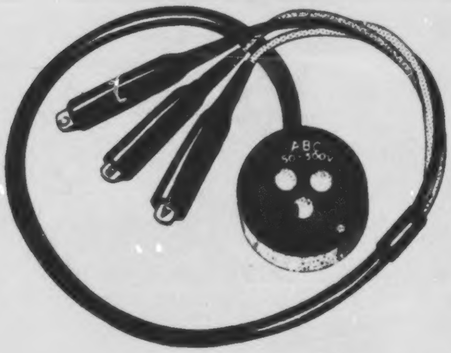
Tests should be made during clear, dry weather. The temperature and relative humidity of the air and general atmospheric conditions should be recorded at the time tests are being made, if known. Test records should be kept since they show when trouble is developing as a result of gradual or sudden deterioration of the insulation or because of local leakage. For example, a 40-megohm reading on the primary winding of a transformer that has been testing about 500 megohms indicates trouble that should be remedied. Low resistance values may require oil samples to be taken from the transformer to determine whether or not the low values may be due to deterioration of the oil.

PHASE SEQUENCE INDICATOR

The PHASE SEQUENCE INDICATOR is a device used to compare the phase rotation of an incoming alternator operated in parallel with an alternator already on the line; or to determine the phase rotation of equipment being put into use for the first time.

The makeup of a phase sequence indicator is as follows: A tiny three-phase induction motor is equipped with three leads, labeled A, B, and C, as shown in figure 5-21. The insulating hoods over the clips are of different colors; red for A, white for B, and blue for C.

The rotor in the instrument can be observed through the three PORTS as it turns, so that

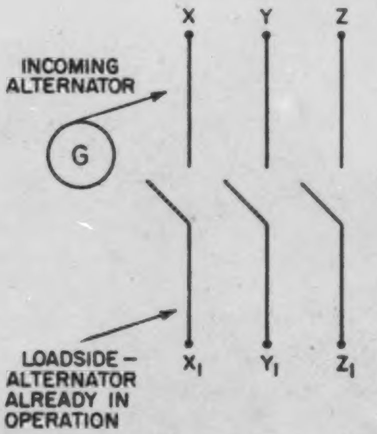


73.52
Figure 5-21. —Phase-sequence indicator.

you can note the direction in which it rotates. The rotor can be started by means of a momentary contact switch; it stops again when you release the switch.

Phase sequence is the sequence or order in which the three voltages of a three-phase system appear. When an incoming alternator is cut in with a loadside alternator already in operation, connections must be made so that the phase sequence of the two will be the same.

Figure 5-22 illustrates the procedure for ensuring this with a phase sequence indicator. Connect indicator terminal A to X_1, B to Y_1, and C to Z_1, press the contact switch, and note the direction of rotation of the rotor.



73.53
Figure 5-22.—Diagram for checking phase sequence.

Now move the A terminal to X, the B to Y, and the C to Z, and again press the switch. If the rotor turns in the same direction as before, the phase rotation is the same and the connection can be made X to X_1, Y to Y_1, and Z to Z_1. If the rotor turns in the opposite direction, transpose the connections of any two of the incoming alternator leads before making the connection.

Now move the A terminal to X, the B to Y, and the C to Z, and again press the switch. If the rotor turns in the same direction as before, the phase rotation is the same and the connection can be made X to X_1, Y to Y_1, and Z to Z_1. If the rotor turns in the opposite direction, transpose the connections of any two of the incoming alternator leads before making the connection.

It is not absolutely necessary that A be connected to the left-hand terminal, B to the center terminal, and C to the right-hand terminal. This is a practical method, however, used to avoid the danger of confusing the leads. The important thing is to ensure that the phase sequence indicator that was used on X_1 be brought down to X, the one used on Y_1 to Y, and the one used on Z_1 to Z. Reversing any two of the leads will reverse the direction of rotation of the rotor.

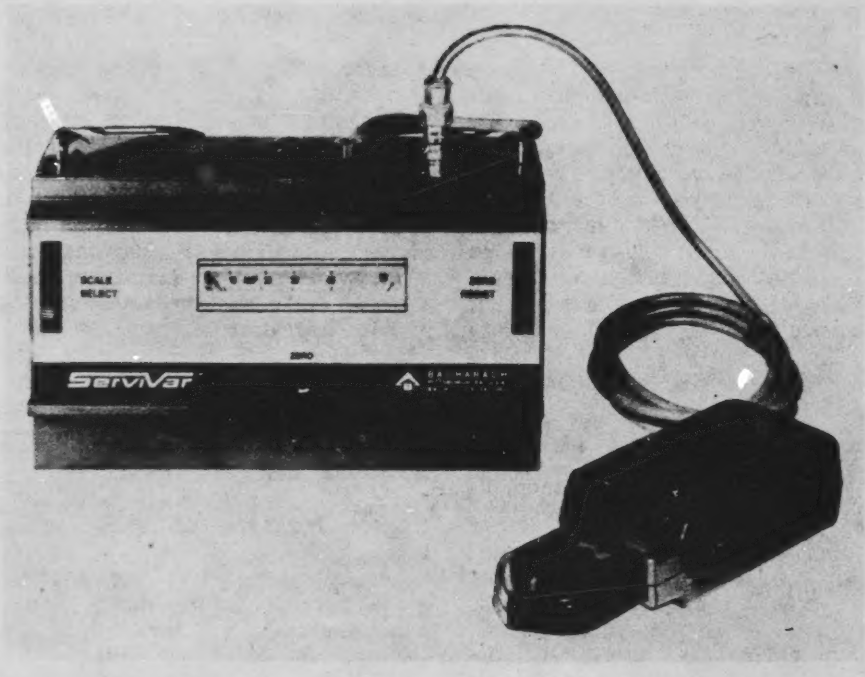
SPECIAL TEST EQUIPMENT

In addition to the basic test instruments described in the previous sections, it is necessary that you acquaint yourself with various special test instruments. A description of a number of special test instruments used by the CE is presented in the following sections.

SERVIVAR ELECTRICAL TESTER

The Servivar Electrical Tester is a multipurpose electrical instrument designed for resistance, and alternating current and voltage measurements. It is a portable, battery-operated unit consisting of the basic indicator instrument (fig. 5-23), an attachable Snap-Around probe for measuring a-c currents (fig. 5-24) and a Line Splitter (fig. 5-25).

Only one scale on the instrument is visible to the user at any given time. This eliminates or reduces confusion and erroneous readings so common to multiple scale instruments. The scales

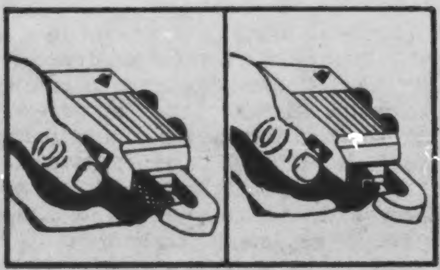


26.230X

Figure 5-23.—Servivar electrical tester.

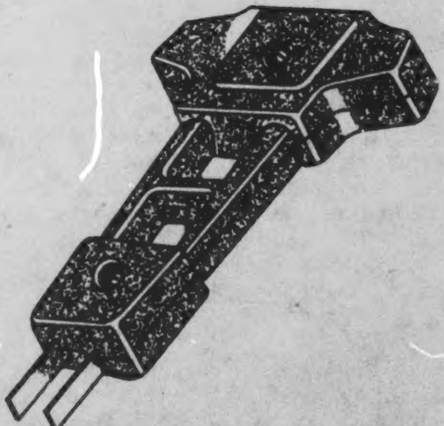
are color coded so that the user can quickly recognize whether he is on the a-c current scale, a-c volt scale, or the ohm scale.

Special circuitry (not shown) prevents damage to the meter when voltage is applied inadvertently to the instrument when it is on the ohm scale. This is accomplished without the use



26.231X

Figure 5-24.—Snap-around probe.



26.232X

Figure 5-25.—Line splitter.

of fuses, circuit breakers, or other devices that would have to be replaced or reset.

Principles of Operation

The a-c current to be measured is intercepted from the conductor in which it is flowing by transformer action in the magnetic path that constitutes the Snap-Around probe. A pick-off coil located inside the probe and around the magnetic path surrounding the reference conductor supplies voltage to a full-wave bridge through a resistance network. This voltage varies in magnitude in direct proportion to the current that is being measured.

Probe

The probe has been designed to enter into cramped electrical boxes and to snap around an individual conductor in a mass of conductors without the need to reposition the other conductors. It operates as a true Snap-Around device that accepts wires up to 0.5 inch outer diameter, rather than a cumbersome scissors type jaw that requires a maximum clearance.

The probes are interchangeable with all indicators so that additional probes may be left permanently installed in inaccessible locations.

The Snap-Around probe features easy thumb control for quick opening. Retraction is a simple operation. Merely slide the thumb knob back and hold at the desired clearance. (See fig. 5-24.) To close, release gently, encircling the wire whose current is to be determined.

Line Splitter

As you know, in measuring a-c current, it is mandatory that only one conductor be encircled. It may not be convenient or possible to split the conductors in a two conductor cable so that a current measurement can be made. The line splitter automatically performs this function.

WESTON MODEL 639 INDUSTRIAL ANALYZER TYPE 3

The Weston Model 639 Industrial Analyzer Type 3 can be used to measure the complete load conditions of any three-phase four-wire system when used with proper current and potential transformers (fig. 5-26). Switches permit testing of 60- or 400-hertz power circuits. The power factor meter and wattmeter are combined into one instrument and selection is made by another switch.

Adapters

Adapters are available for use on single- and three-phase, 3-wire measurements and may expedite testing procedure. These adapters include: Model 9815 Type 1 Adapter for three-phase 3-wire 200/100/50/5-ampere operation; Model 9815 Type 2 Adapter for single-phase 2-wire 100-ampere operation; and Model 9815 Type 3 Adapter for single-phase 2-wire 50-ampere operation.

Precautions

You should remember the following precautions when using the analyzers:

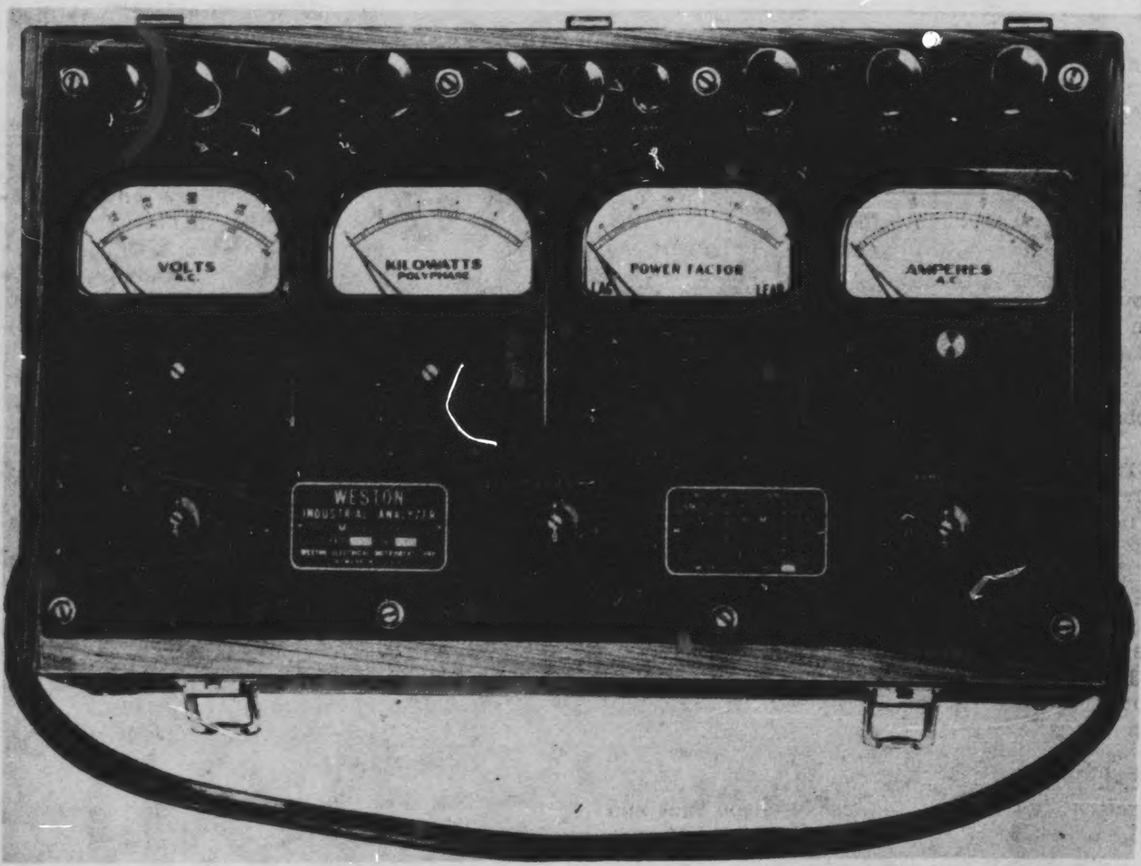
1. Always set switches to the proper settings and ranges before connecting the instrument.
2. Always connect the load leads to the same current on all three phases of the instrument and to a high enough range so that the current indicated will be below the full scale deflection of the ammeter.
3. NEVER USE THESE INSTRUMENTS FOR D-C MEASUREMENTS.

Connecting Analyzer to Circuits

The three-phase, 4-wire hookup in figure 5-27 shows a schematic of external potential and current transformers. Improper connection could result in damage to personnel and equipment. Therefore, follow the manufacturer's instructions carefully when connecting analyzers to circuits.

Ensure that all cables used for connections to source or load are of sufficient size to carry the currents involved and are connected securely to the binding posts and the circuit terminals. Refer to Table 310-13 (National Electric Code) for information regarding the allowable ampacities of insulated copper conductors, for more data pertaining to cables.

BE SURE TO USE THE APPROPRIATE CORRECTION FACTOR (bottom of Table 310-13) wherever the ambient temperature exceeds 86° F. For example, if you plan to use THW conductor, and the ambient temperature at your station is 113° F, notice that the current carrying capacity of the size of wire you intend to use



26.29X

Figure 5-26.—Weston Industrial Analyzer, model 639.

will be reduced 18 percent and be equivalent to 82 percent of that listed in Table 310-13.

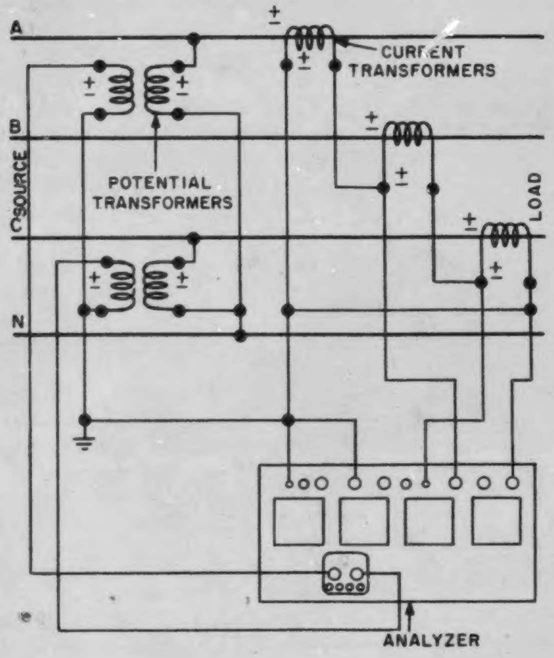
The most convenient place to make connections is at the fuse block, by using dummy fuses with cables attached (fig. 5-28). The cables connected to these dummy fuses may be connected to the analyzer. When an interruption to service will be convenient, it is only necessary to remove the good fuses from the cutout and insert the dummy fuses with cables attached.

As a word of caution, disconnect the circuit by opening the main line switch before removing fuses and inserting dummy fuses. This may be done very quickly. This method is only a suggestion and may not always be practical. When using this method be certain that the circuit is protected by other fuses or circuit breakers as these dummy fuses remove the protection at that point.

MULTIAMP TESTER (MS-1A)

In a later chapter you will learn the importance of maintaining circuit breakers, relays, controllers and other protective devices in proper condition. How do we know whether or not these devices will perform as designed—to trip at rated value?

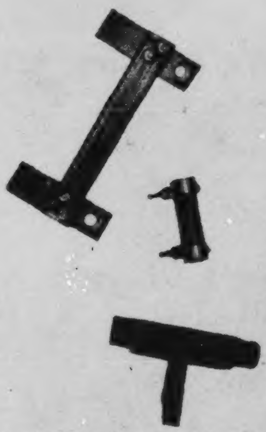
The portable device described here has as its main function exactly these purposes—to check protective devices. It checks most types of protective relays as well as small circuit breakers, fuses, and insulation resistance.



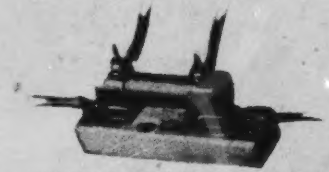
TWO POTENTIAL TRANSFORMERS OF SUITABLE RANGE HAVING 115 VOLT SECONDARIES CONNECTED FROM NEUTRAL TO LINES "A" AND "C". THREE CURRENT TRANSFORMERS OF SUITABLE RANGE HAVING 5 AMPERE SECONDARIES CONNECTED IN DELTA.

26.40X

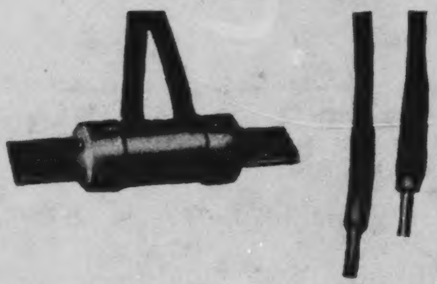
Figure 5-27.—Three-phase, 4-wire circuit connected to three current transformers.



VARIOUS TYPES OF CUT-OUT FUSES FOR MEASURING CURRENT WITHOUT INTERRUPTING SERVICE



DUMMY CARTRIDGE FUSE IN USE



26.31X

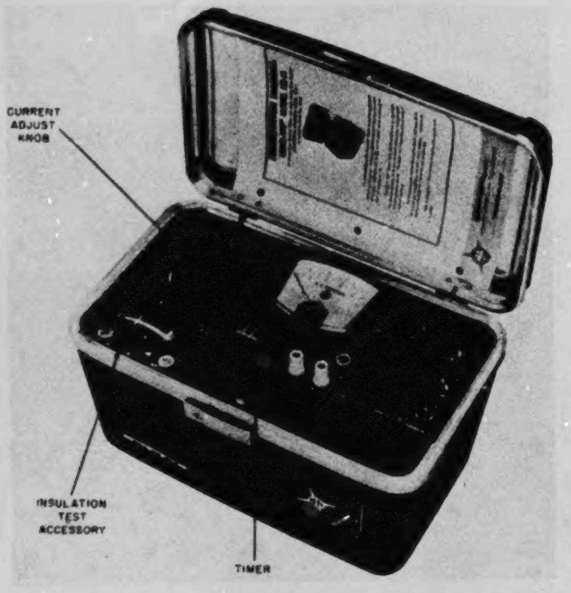
Figure 5-28.—Various types of dummy fuses.

The instrument test relays from 0.1 to 100 amperes and circuit breakers up to 100 ampere capacity, measuring accurately the time-current characteristics of these devices with a synchronous electronically actuated timer.

The MultiAmp (MS-1A) instrument (fig. 5-29) is used primarily in Public Works installations. Testing is rapid. It takes but a few minutes to know your equipment is properly protected.

The instrument can be used to check the overload heaters of small motors. Refer to manufacturer's data sheets or Allowance Parts Lists for the tripping time characteristics for the particular overload heater. After setting the Current Adjust knob to that current which is supposed to trip the device and noting on the Timer the time it takes for the device to trip, a comparison is made with the manufacturer's specifications. Obviously, any results beyond the specified limits will indicate a defective relay which should be replaced or, if adjustable, reset to meet the specifications.

Use of this instrument will expedite determination of relay malfunctions or circuit faults. Assured of relay accuracy, after testing, you know the cause of difficulty (if the relay keeps tripping) lies within the circuitry other than the relay and must be sought there.



26.224X

Figure 5-29.—MultiAmp model MS-1A test set.

An accessory to the MS-1A tester, used for insulation measurements, fits into the accessory socket in the test lead compartment (fig. 5-29). With it, insulation measurements from 2 to 1000 megohms with ±5 percent accuracy can be made.

MODEL 259 VIBROGROUND

Electrical systems and specific electrical equipment must be protected from damage or destruction by voltages from other circuits, or lightning. Manmade grounds provide this safety feature. To provide maximum protection, these grounds must be checked regularly.

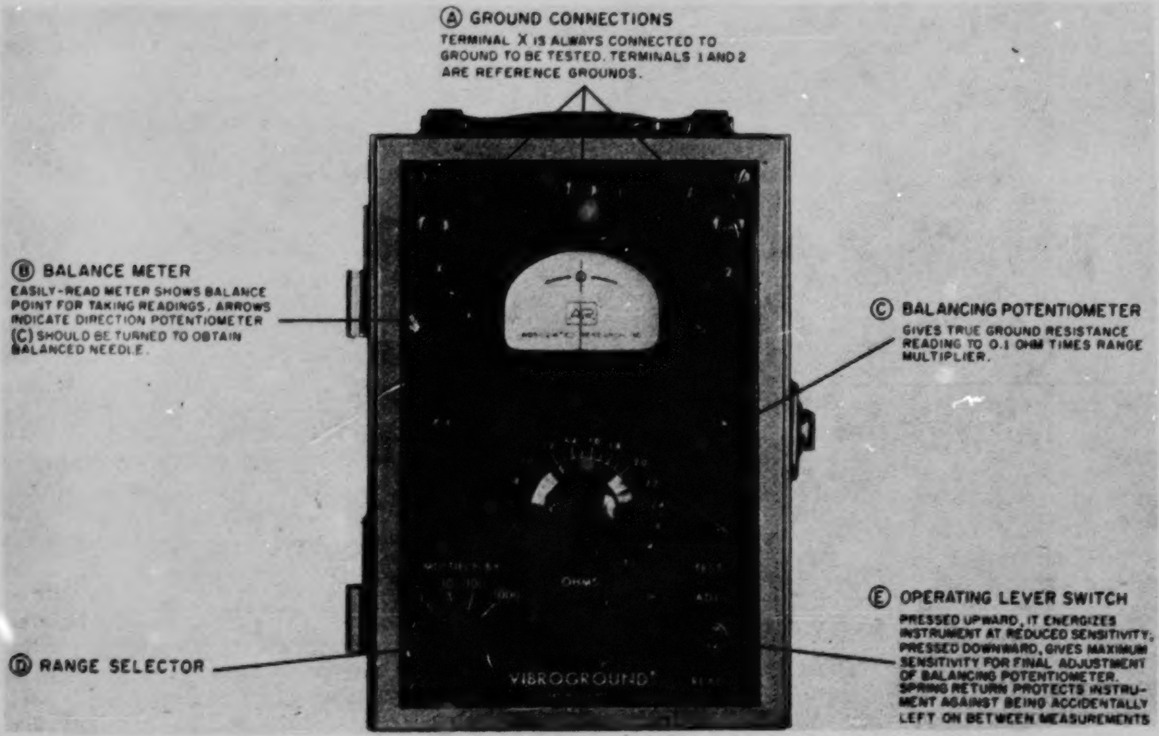
Figure 5-30 shows the Vibroground, an instrument specifically designed to check grounds quickly and accurately.

The Vibroground works on a null-balance principle. The basic circuit is indicated in figure 5-31. The voltage drop developed by a current flowing through the unknown ground resistance is measured by comparing it to a portion of the voltage drop developed by that same current flowing through a calibrated potentiometer. The current flowing through the calibrated potentiometer causes a voltage drop which is fed to the primary of the ratio transformer, inducing a voltage in the secondary, causing a current flow in the measuring circuit. This current tends to cancel the existing current in the measuring circuit due to the voltage drop across the ground resistance between the electrodes connected to terminals X and 1. When the calibrated potentiometer and range switch are adjusted so that the two currents exactly cancel, the galvanometer will indicate balance by resting in the zero position. The reading on the calibrated dial of the potentiometer, multiplied by the range switch setting, then gives the value of the ground resistance of the point under test.

Representative test setups are shown in figures 5-32 and 5-33.

Grounding must be in accordance with the National Electrical Code, published by the National Board of Fire Underwriters and the National Electrical Safety Code, published by the U. S. Department of Commerce, National Bureau of Standards, except that grounds and grounding systems must have a resistance of solid earth ground not exceeding the following values:

	Ohms
Generating stations	1
Main substations, distribution substations, and switching stations on primary distribution system	3
Metal enclosures of electrical and electrically operated equipment and cable sheaths of connecting cables	3
Systems to which portable electrical utilization equipment or appliances are connected	3
Secondary distribution systems (neutral), noncurrent carrying metal parts associated with distribution systems, and enclosures of electrical equipment not normally within reach of other than authorized and qualified electrical operating and maintenance personnel.	10
Individual transformer and lightning arrester grounds on a distribution system.	10
Equipment not covered above.	10


Ⓐ GROUND CONNECTIONS
TERMINAL X IS ALWAYS CONNECTED TO GROUND TO BE TESTED. TERMINALS 1 AND 2 ARE REFERENCE GROUNDS.
Ⓑ BALANCE METER
EASILY-READ METER SHOWS BALANCE POINT FOR TAKING READINGS. ARROWS INDICATE DIRECTION POTENTIOMETER (C) SHOULD BE TURNED TO OBTAIN BALANCED NEEDLE.
Ⓒ BALANCING POTENTIOMETER
GIVES TRUE GROUND RESISTANCE READING TO 0.1 OHM TIMES RANGE MULTIPLIER.
Ⓓ RANGE SELECTOR
Ⓔ OPERATING LEVER SWITCH
PRESSED UPWARD, IT ENERGIZES INSTRUMENT AT REDUCED SENSITIVITY; PRESSED DOWNWARD, GIVES MAXIMUM SENSITIVITY FOR FINAL ADJUSTMENT OF BALANCING POTENTIOMETER. SPRING RETURN PROTECTS INSTRUMENT AGAINST BEING ACCIDENTALLY LEFT ON BETWEEN MEASUREMENTS
OHMS
VIBROGROUND

1.55AX

Figure 5-30.— Vibroground test set.

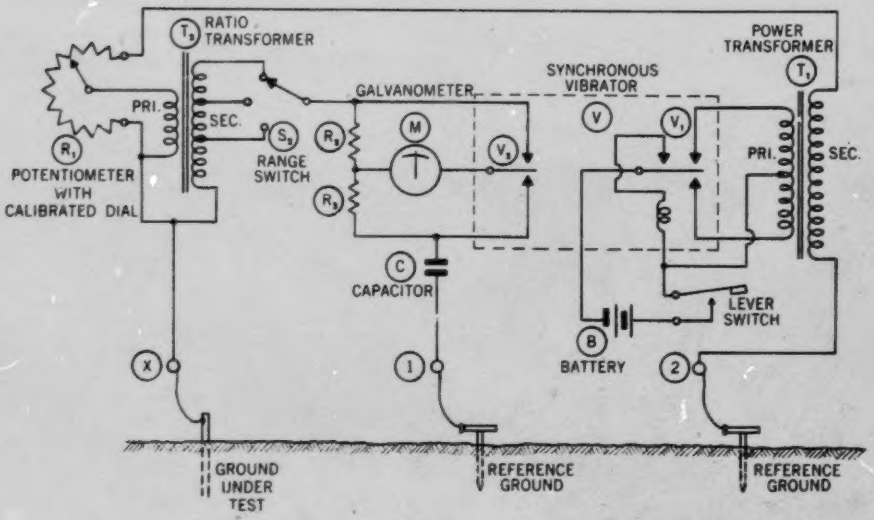
Where practicable, electrically continuous metallic buried water piping should be utilized for grounding electrodes. Artificial grounding electrodes, where required, should be the sectional type driven ground rods of cone-pointed, copper-encased steel or solid copper. Approved copper-alloy clamps must be brazed to the upper end of ground rods, and ground wires securely attached thereto by means of a bolted connection. Each ground rod must be die-stamped near the top with the name or trademark of the manufacturer and the length of the rod in feet. Ground rods should be driven to a depth of not less than 8 feet and should have diameters sufficient to permit driving to the necessary depth without being damaged. In no case, however, should they be less than 5/8 inch in diameter.

WHEATSTONE BRIDGE

The Wheatstone Bridge (fig. 5-34) may be used to measure the resistance of a pair of wires in a telephone cable, or to locate the distance to a fault (ground) in the cable by either of two methods: the Varley (Var) loop test or the Murray (Mur) loop test.

Preoperational Test

Place the instrument on a level surface as near as possible to the test point and follow the preoperational test procedure indicated in the manufacturer's instruction manual.


RATIO TRANSFORMER
T_2
PRI.
SEC.
R_1
POTENTIOMETER WITH CALIBRATED DIAL
S_2
RANGE SWITCH
R_2
R_3
GALVANOMETER
M
V_2
SYNCHRONOUS VIBRATOR
V
V_1
POWER TRANSFORMER
T_1
PRI.
SEC.
C
CAPACITOR
LEVER SWITCH
B
BATTERY
X
1
2
GROUND UNDER TEST
REFERENCE GROUND
REFERENCE GROUND

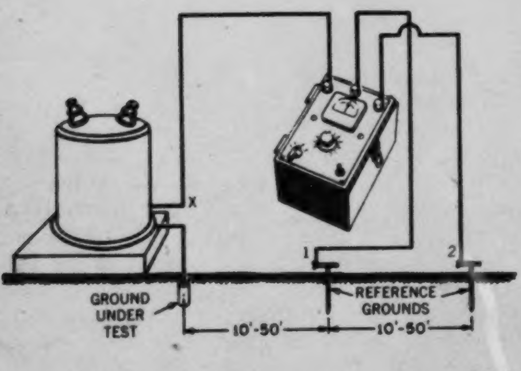
1.55AX

Figure 5-31.—Basic Vibroground circuit.

Measurement of Unknown Resistances

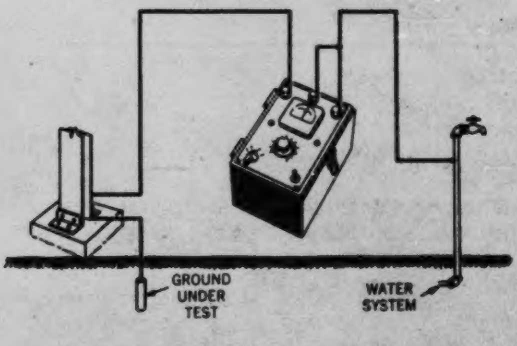
Once the instrument accuracy has been verified, and the resistance of a loop or other resistance is to be determined, measurement can be easily made by referring to table 5-1 and setting the MULTIPLY BY dial to that setting closest to the estimated value of the unknown resistance.

If the resistance of a loop is to be determined, disconnect all equipment from the near end of the loop and connect one wire of the loop to the binding post X_1 and the other wire to line binding post X_2 (fig. 5-35). Be sure that the wires connected to the test set are clean and firmly secured to the binding posts. Have all equipment disconnected from the far


X
1
2
GROUND UNDER TEST
REFERENCE GROUNDS
10'-50'
10'-50'

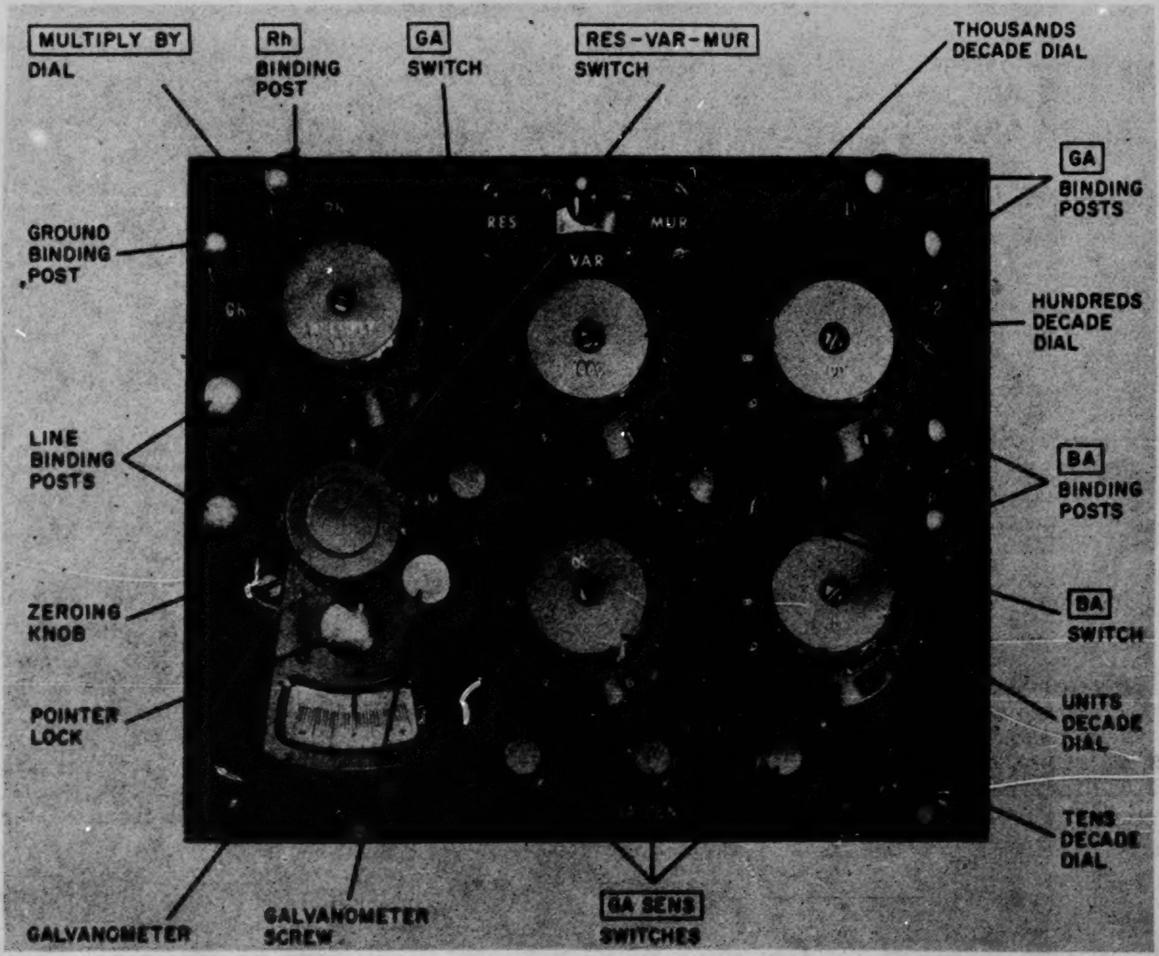
26.227X

Figure 5-32.—Vibroground test setup for checking the resistance to earth of a driven transformer ground.


GROUND UNDER TEST
WATER SYSTEM

26.228X

Figure 5-33.—Vibroground test setup when there is a well established low resistance reference ground.


MULTIPLY BY
DIAL
Rh
BINDING POST
GA
SWITCH
RES-VAR-MUR
SWITCH
THOUSANDS DECADE DIAL
GA
BINDING POSTS
GROUND BINDING POST
HUNDREDS DECADE DIAL
LINE BINDING POSTS
BA
BINDING POSTS
ZEROING KNOB
BA
SWITCH
POINTER LOCK
UNITS DECADE DIAL
TENS DECADE DIAL
GALVANOMETER
GALVANOMETER SCREW
GA SENS
SWITCHES
RES
VAR
MUR

26.43.2

Figure 5-34.—Wheatstone Bridge operating controls.

end of the loop and a short placed across the circuit at that end.

If the resistance of an electrical component is to be measured, connect the component across line binding posts X_1 and X_2.

The bridge is balanced and the test procedure complete when the GA SENS switches (fig. 5-34) are pressed in proper sequence and the pointer on the galvanometer does not move in either direction. Resistance is determined by summing up the decade dial settings and multiplying that result by the setting of the MULTIPLY BY dial.

Regular Varley Loop Test

The regular Varley loop test (fig. 5-36) is used to locate a ground in a high-resistance loop when the imbalance (difference in resistance between the faulty and good wires) does not exceed 1 ohm. The regular Varley method requires the use of one good wire between the test point and the far end of the circuit.

Location of the ground can be achieved using the following formula, all of which are derived from the original Wheatstone Bridge. (Refer to the Regular Varley Loop test circuit (fig. 5-37.)

Table 5-1.—Multiply by Dial Setting When Measuring Resistance

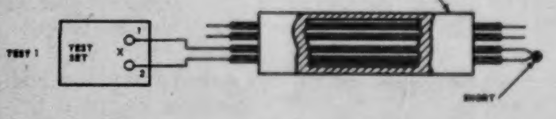
ESTIMATED RESISTANCE (ohms)	MULTIPLY BY dial setting
Below 10	$\frac{1}{1000}$
10 to 100	$\frac{1}{100}$
100 to 1,000	$\frac{1}{10}$
Used in Varley tests	$\frac{1}{9}$
Used in Varley tests	$\frac{1}{4}$
1,000 to 10,000	$\frac{1}{1}$
10,000 to 100,000	$\frac{10}{1}$
100,000 to 1,000,000	$\frac{100}{1}$

73.340

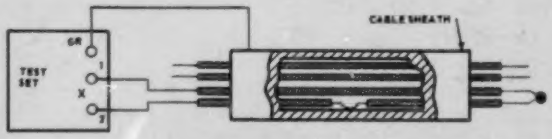
(1) The equation used to determine the resistance from test point to fault (X_a) equals:

$$X_a = \frac{rB - AR}{A + B}$$

where r equals $R_g + R_b$ (loop resistance).



26.44
Figure 5-35.—Connection for measurement of loop resistance.



26.45
Figure 5-36.—Connections for ground location, regular Varley and Murray loop tests.

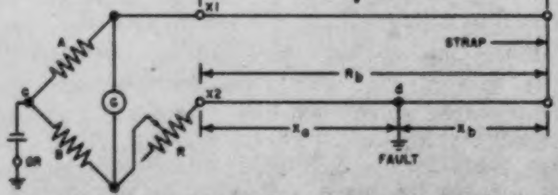
(2) The equation used to determine resistance from far end to fault (X_b) equals:

$$X_b = \frac{A(R + R_b) - BR_g}{A + B}$$

where A = numerator of position of MULTIPLY BY dial,
B = denominator of position of MULTIPLY BY dial,
r = loop resistance as calculated in previous paragraph, Measurement of Unknown Resistance,
R = decade dial reading after balancing,
R_g = resistance of good wire from test point to far end,
R_b = resistance of faulty wirs from test point to far end.

Three Varley Test

This test has a definite advantage, especially for central desk testing, over other types of tests in that the resistance of the test cords and the conductors themselves neither need to be



26.46.1
Figure 5-37.—Regular Varley loop test circuit, simplified schematic diagram.

known nor allowed for in the calculations. Its chief drawback lies in the fact that a good pair (two conductors of any resistance) are needed in addition to the faulty conductor and ground.

NOTE: Lead wires and conductors may be of unequal resistance, because this method balances out their resistances.

The test derives its name from the Varley Loop and from the fact that three such tests must be made. However, each is simple as shown in the diagrams and any tester who can perform the simple Varley should achieve accurate results here. (See fig. 5-38 (a), (b), and (c).) The three tests made are known as "Varley 1", "Varley 2" and "Varley 3", using the connections as shown in figure 5-38 (a), (b), and (c).

Calling the rheostat readings at balance R_1, R_2, and R_3 respectively, the basic equations are:

$$\frac{A}{B} = \frac{R_g}{R_1 + R_b} = \frac{R_g + X_b}{R_2 + X_a} = \frac{R_g + R_b}{R_3}$$

From which may be obtained the working equations:

$$X_a = \frac{A}{A + B} \times (R_3 - R_2)$$

used to determine the resistance (X_a) between the test point and the fault.

$$X_b = \frac{A}{A + B} \times (R_2 - R_1)$$

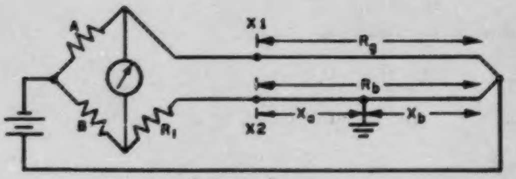
used to determine the resistance (X_b) between the fault.

$$R_b = X_a + X_b = \frac{A}{A + B} \times (R_3 - R_1)$$

used to determine the resistance (R_b) of the full length of the faulty wire.

These symbols are identified in equation 2 under Regular Varley Loop Test.

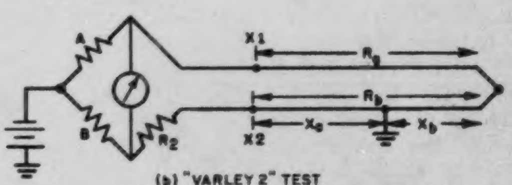
In using the three Varley Test, MULTIPLY BY dial ranges 1/1, 1/4, or 1/9 are recommended. Once the range has been selected, it must be used on all three tests to produce accurate results.



(a) "VARLEY 1" TEST

VARLEY 1 TEST BASIC EQUATION:

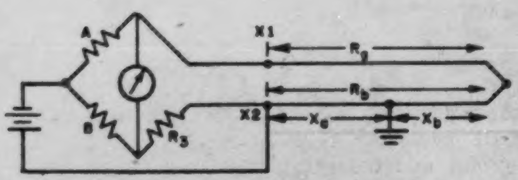
$$\frac{A}{B} = \frac{R_g}{R_b + R_1}$$



(b) "VARLEY 2" TEST

VARLEY 2 TEST BASIC EQUATION:

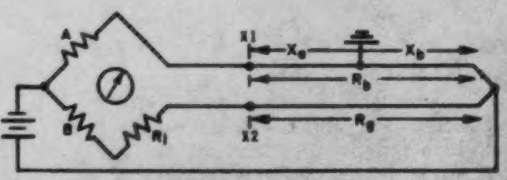
$$\frac{A}{B} = \frac{R_g + X_b}{X_a + R_2}$$



(c) "VARLEY 3" TEST

VARLEY 3 TEST BASIC EQUATION:

$$\frac{A}{B} = \frac{R_g + R_b}{R_3}$$



(d) MODIFIED "VARLEY 1" TEST

NOTE: CONNECTIONS OF POSITIVE PORTION OF BATTERY DISTINGUISH BETWEEN THE THREE VARLEY TESTS.

26.46.2

Figure 5-38.—Simplified schematics and basic equations for "Three Varley tests."

To determine the resistance to the fault to tenths of an ohm, the ratio A/B must be approximately 1/10. The ratio 1/9 and 1/4 are convenient in some models, because their working equations reduce, respectively, to the forms:

$$X_b = \frac{R_2 - R_1}{10},\ X_a = \frac{R_3 - R_2}{10},\ \text{and } R_b = \frac{R_3 - R_1}{10}$$

$$X_b = \frac{R_2 - R_1}{5},\ X_a = \frac{R_3 - R_2}{5},\ \text{and } R_b = \frac{R_3 - R_1}{5}$$

When the total resistance of the loop is more than about 1000 or 1100 ohms, it is impossible to balance the bridge when using the 1/10 or 1/9 MULTIPLY BY dial setting. It may then be necessary to use A/B = 1. Then, if the good wire is of lower resistance than the faulty wire, the bridge cannot be balanced in the "Varley 1" test. The good and bad wires, with their leads, must interchanged as in figure 5-38 (d), while making the "Varley 1" test only. The working equations under these conditions are:

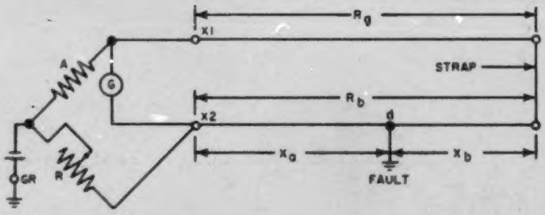
$$X_b = \frac{R_2 + R_1}{2},\ X_a = \frac{R_3 - R_2}{2}\ \text{and } R_b = \frac{R_3 - R_1}{2}$$

To avoid the need for interchanging the good and bad conductors in the "Varley 1" test, a small resistor may be connected between the test set and the good conductor. It is used during all three tests. Any reasonable value of resistance may be used which is large enough to make the resistance of the good conductor higher than that of the bad one. Its value need not be known since it is automatically eliminated by this method of test.

Murry Loop Test For Locating a Ground

To use the Murray loop test for locating a ground, a good wire should be available (fig. 5-36) in addition to the grounded wire. A simplified schematic is shown in figure 5-39. Remove all equipment from both ends of the circuit and locate the fault using the manufacturer's instructions and either of the following methods:

(a) Direct computation, for solving d_a, the distance from the test point to the fault, when total mileage of loop is known.



26.46.3

Figure 5-39.—Regular Murray loop test for locating ground.

$$d_a = \frac{R \times L}{R + A},$$

where R equals the decade dial sum, L equals the total loop distance in miles and A equals the MULTIPLY BY dial reading (usually set at M 10, M 100, or M 1000 for Murray Loop readings).

(b) Resistance-distance method is used after the resistance X_a (from the test point to the fault) has been determined using the formula

$$X_a = \frac{R \times r}{R + A},$$

where R = total decade dial reading.

r = total loop resistance of the faulty circuit

A = numerator of the position of MULTIPLY BY dial.

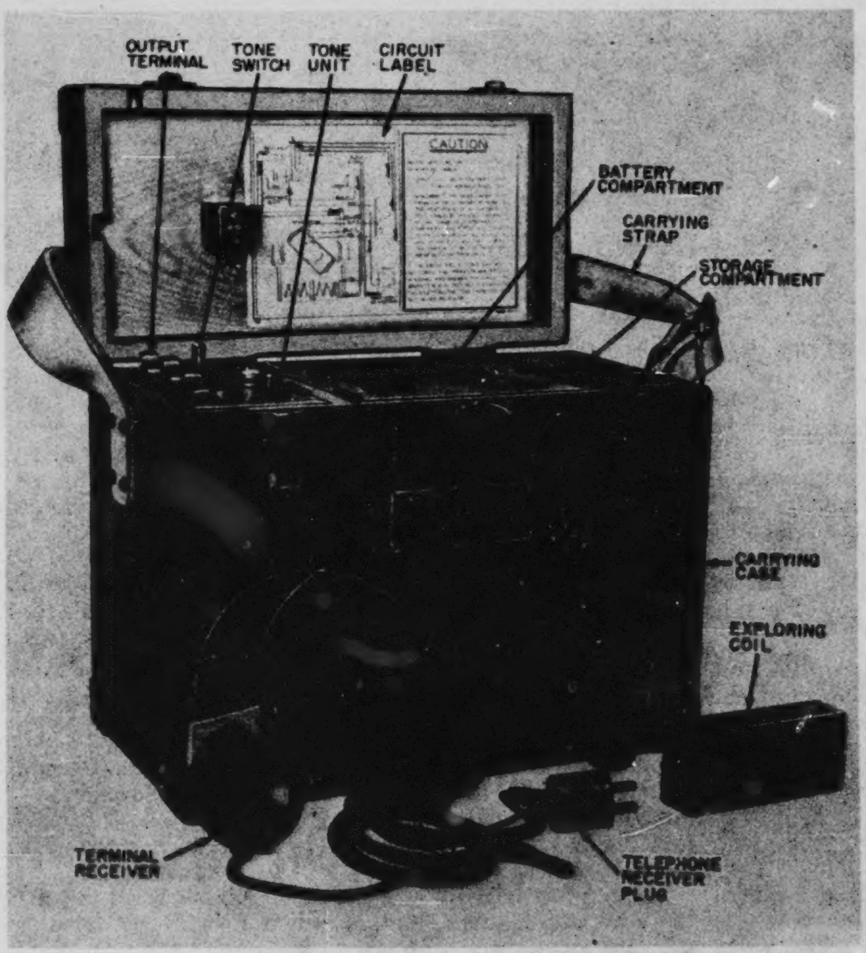
The result obtained from the above calculation is then substituted in

$$d_a = \frac{X_a}{1/2 \text{ resistance per loop mile}},$$

and should agree with the result calculated by the direct computation method.

CABLE REPAIRMAN'S TEST SET

The cable repairman's test set, I-51 (fig. 5-40) is used to pinpoint the location of cable faults after the approximate location of the fault has been obtained by the use of the Wheatstone Bridge or some other method. The test set can be used to locate shorts, grounds, crosses, split pairs, wet spots, and similar troubles in a cable. IT CANNOT BE USED TO LOCATE OPEN CIRCUITS.


OUTPUT TERMINAL
TONE SWITCH
TONE UNIT
CIRCUIT LABEL
CAUTION
BATTERY COMPARTMENT
CARRYING STRAP
STORAGE COMPARTMENT
CARRYING CASE
EXPLORING COIL
TERMINAL RECEIVER
TELEPHONE RECEIVER PLUG

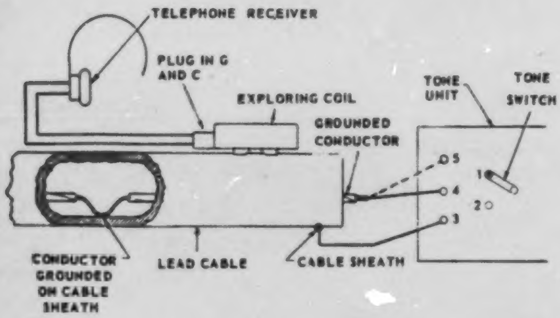
26.47

Figure 5-40.—Cable repairman's test set I-51.

The test set includes a tone unit, an exploring coil equipped with three jacks, and a telephone receiver equipped with a cord and plug for connection to the exploring coil packs. The tone unit has a switch for selecting steady or interrupted tone and a set of terminals for connecting the tone unit to the faulty conductors. These units are housed in a carrying case which is provided with an adjustable carrying strap. The inside of the carrying case is divided into three compartments: one for the tone unit, one for the batteries, and one for storing the exploring coil and the receiver. In addition to the components supplied with the test set, it is necessary to have four (BA-23) batteries to furnish the required 6 volts, two alligator clips and approximately 10 feet of two-conductor cable required to assemble the test cord.

Operating Procedures

Before you use the test set, study your instruction manual. Obtain information from the central office personnel on the type of cable fault, the resistance of the faulty conductors, and the approximate location of the fault.

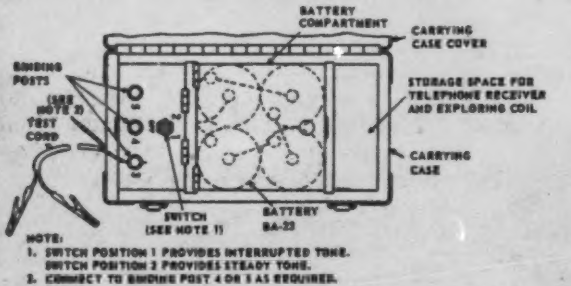

TELEPHONE RECEIVER
PLUG IN G AND C
EXPLORING COIL
TONE UNIT
TONE SWITCH
GROUNDED CONDUCTOR
5
1
4
2
3
CONDUCTOR GROUNDED ON CABLE SHEATH
LEAD CABLE
CABLE SHEATH

26.49
Figure 5-41.—Connections for locating ground.

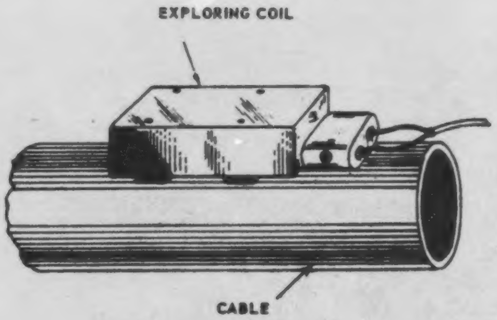
Location of Grounds

Grounds are located by making connections and setting controls as shown in figs. 5-41 and 5-42. Note that regardless of how much resistance exists between the point where the tone is applied and the probable location of the fault, binding post 3 is always used. Use binding posts 3 and 4 for cable faults having a resistance of less than 100 ohms between those points and binding posts 3 and 5 for those 100 ohms or more.

At the approximate location of the fault, place the telephone receiver in position over one ear and hold the exploring coil parallel to the cable as shown in figure 5-43. Be sure that the telephone receiver plug is inserted into the G and C jacks of the exploring coil (fig. 5-41.)


BATTERY COMPARTMENT
CARRYING CASE COVER
BINDING POSTS
(SEE NOTE 2)
TEST CORD
STORAGE SPACE FOR TELEPHONE RECEIVER AND EXPLORING COIL
CARRYING CASE
SWITCH (SEE NOTE 1)
BATTERY BA-23
NOTE:
1. SWITCH POSITION 1 PROVIDES INTERRUPTED TONE. SWITCH POSITION 2 PROVIDES STEADY TONE.
2. CONNECT TO BINDING POST 4 OR 5 AS REQUIRED.

26.48
Figure 5-42.—Test set, top view, with cover open.


EXPLORING COIL
CABLE

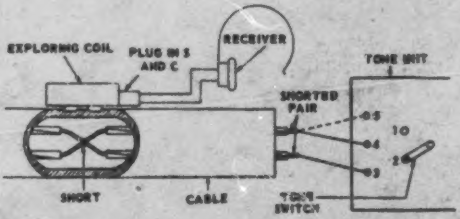
26.50
Figure 5-43.—Position of exploring coil for locating grounds, shorts, or split pairs.

While listening with the receiver, move the exploring coil along the cable toward the fault until the tone disappears or the volume of the tone is markedly decreased. This should be the exact location of the fault.

In high resistance faults, the tone will not disappear when the fault is passed because of a carryover effect of the line capacitance. In some cases, the change in volume is so slight that an absolute location of the fault is uncertain. In such cases, place a chalk mark at the approximate location, then transfer the test set to the other end of the cable, and repeat the steps given above.

Location of Shorts

An insulation breakdown between the two conductors of a pair which permits the two wires to touch each other will cause a short circuit.


EXPLORING COIL
PLUG IN S AND C
RECEIVER
TONE UNIT
SHORTED PAIR
5
10
4
2
3
SHORT
CABLE
TONE SWITCH

26.51
Figure 5-44.—Connections for locating shorts.

A short may also occur if moisture enters the cable sheath and reduces the insulation resistance between the two wires of the pair to the point where the conductors cannot be used efficiently.

In locating shorts with the cable repairman's test set, make connections as shown in fig. 5-44.

At the approximate location of the fault, place the telephone receiver plug in position over one ear and hold the exploring coil parallel to the cable as shown in figures 5-43 and 5-44. Be sure that the telephone receiver plug is inserted in S and C jacks of the exploring coil. (See fig. 5-44.)

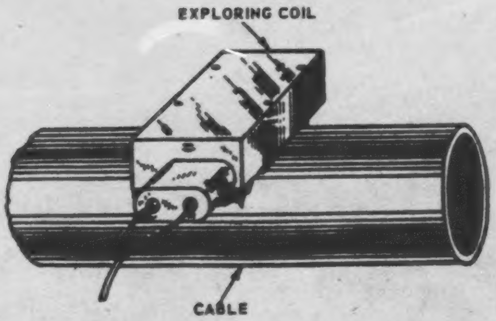
While listening with the receiver, move the exploring coil along the cable toward the fault. The tone will decrease and increase in volume as the coil is moved along the cable. This is called the short-circuited effect. When the coil is moved over the fault, the tone will decrease considerably in volume or disappear entirely.

If uncertain of the exact location, transfer the test set to the other end of the cable and repeat the steps given above.

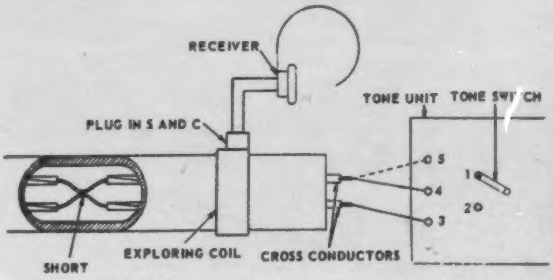
Location of Crosses

A cross is essentially the same as a short except that the contact is between conductors from two different pairs.

To locate crossed wires, make connections and hold the exploring coil as shown in figures 5-45 and 5-46.



26.52
Figure 5-45.—Position of exploring coil for locating crosses and wet spots.



26.53
Figure 5-46.—Connections for locating crossed wires.

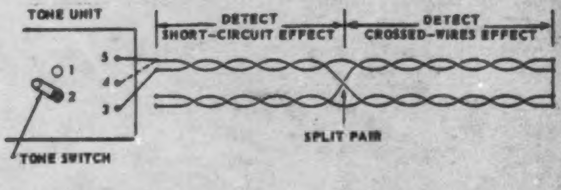
While listening with the receiver, move the exploring coil along the cable toward the fault until the tone fades out or is reduced considerably in volume. The steady volume tone heard while tracing crossed wires is known as the crossed-wires effect. If uncertain of the exact location of the fault, place a chalk mark at the approximate location, then transfer the test set to the other end of the cable and repeat the steps given above.

Location of Split Pairs

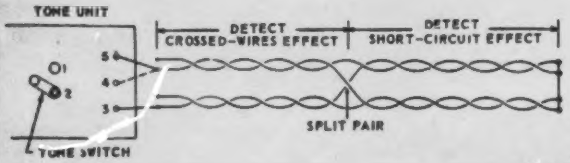
A split pair is caused by splicing error in which one wire of a pair is connected to one wire of another pair.

Make connections as shown in fig. 5-47 and hold the exploring coil parallel to the cable as shown in fig. 5-43 to locate a split pair.

While listening with the receiver, move the exploring coil along the cable toward the fault. The tone will increase and decrease in volume (short-circuit effect) up to the location of the fault and, thereafter, will be steady in volume (crossed-wires effect).



26.54
Figure 5-47.—Connections for locating split pairs.



26.55
Figure 5-48.—Alternative connections for locating split pairs.

To ensure accurate location of the fault, mark the cable at the location found above, and then use the alternative method of locating split pairs described below as a check.

Alternative Method of Locating Split Pairs

Connect the output terminals of the test set to one wire of one of the split pair (strapped at the far end of the cable) and to one wire of the other pair as shown in figure 5-48.

While listening with the receiver, move the exploring coil along the cable toward the fault. The tone will be steady in volume (crossed-wire effect) until the fault is reached; thereafter the tone will increase and decrease in volume (short-circuit effect). It is possible to connect the test set in such a manner that the short-circuit effect will not be detected. If this happens, reconnect one of the test leads to the other wire of the pair to which it is connected. The short-circuit effect now should be heard as described above.

Location of Wet Spots

Normally a wet spot in a cable is caused by an opening in the cable sheath. In aerial cables, this opening can be caused by squirrels chewing on the cable sheath or by tree limbs, cable rings, or cable lashing wire rubbing against the sheath. In underground cables, an opening in the sheath normally is caused by soil erosion or electrolysis. When an opening appears in the sheath, moisture eventually enters the cable and forms a combination of grounds, short circuits, and crosses.

In locating wet spots with the test set, connect the output terminals to each group of strapped wires (fig. 5-49) and set the tone switch to position 1.

At the approximate location of the fault, place the telephone receiver in position over one ear and hold the exploring coil at right angles to the cable as shown in figure 5-45. Be sure that the telephone receiver plug is inserted into the S and C jacks of the exploring coil.

While listening with the receiver, move the exploring coil along the cable toward the fault. A steady tone will be heard up to the location of the fault and, thereafter, the tone will either decrease considerably in volume or disappear entirely.

To ensure accurate location of the fault, mark the cable at the location found above, and use the alternative method of locating wet spots described below as a check.

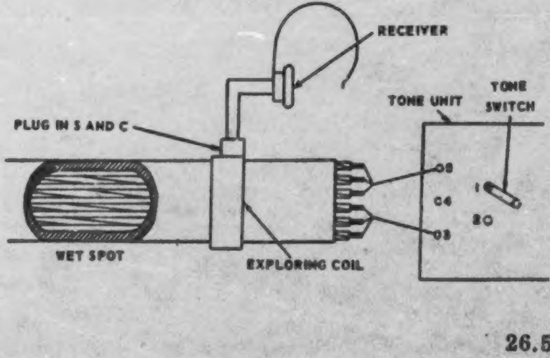
Alternative Methods for Locating Wet Spots

Strap together one group of wires which have a low resistance to ground.

Connect one output terminal of the test set to the cable sheath and the other to the strapped group of wires. Leave the tone switch set to position 1.

At the approximate location of the fault, place the telephone receiver in position over one ear and hold the exploring coil parallel to the cable, as shown in figure 5-43. Be sure that the telephone receiver plug is inserted into the G and C jacks of the exploring coil.

While listening with the receiver, move the exploring coil along the cable toward the fault until the tone disappears or the volume of the tone is markedly decreased, which indicates the exact location of the fault.



26.56
Figure 5-49.—Connections for locating wet spots.

Location of Buried Cable

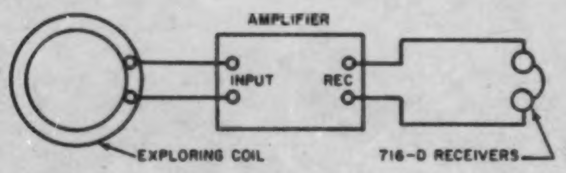
It sometimes becomes necessary to trace the unknown path of a buried cable. When there is trouble in a buried cable, much excavation may be avoided if the exact location of the cable can be determined. Only the tracing methods directly applicable to buried cable are discussed in this section.

In conjunction with the cable repairman's test set I-51, the following items of equipment are required for tracing buried cable:

Amplifier--------	BC-1388
Coil-------------	24- or 26-inch diameter exploring induction coil
Receivers-------	Two No. 716-D receivers equipped with a WECo R2CF cord and a WECo 11a headband
Rods------------	Two ground rods, GP-26

The exploring coil is not available as a standard item, but can be constructed locally as follows:

Wind approximately 300 turns of No. 24-gage double cotton-covered copper wire on a light circular frame with a diameter of 24 or 26 inches to make the coil. Then bring the two ends of the windings about 1/2 inch apart from the side of the coil. Wrap a layer of rubber tape and then a layer of friction tape in the reverse direction over the wound wire, bringing the ends of the wire out of the coil between the layer of the tapes. Terminate the ends of the winding by soldering them to binding posts mounted in a small insulating strip. A piece of hard rubber 3/16 inch by 3/4 inch by 2 1/2 inches will serve satisfactorily as the strip. Apply two coats of asphalt paint to the entire coil. Then fasten the terminal strip to the inside of the completed coil.



26.57

Figure 5-50.—Exploring coil for tracing buried cable.

In an emergency any fine-gage insulated wire wound into a coil about 2 feet in diameter can be used in place of the coil described above.

Under some conditions, the pickup of the exploring coil will be sufficient to give a suitable signal when connected directly to the No. 716-D receivers. If the signal is not strong enough to permit tracing, an amplifier, such as the BC-1388, is connected to the listening circuit. Figure 5-50 shows a schematic view of the exploring coil.

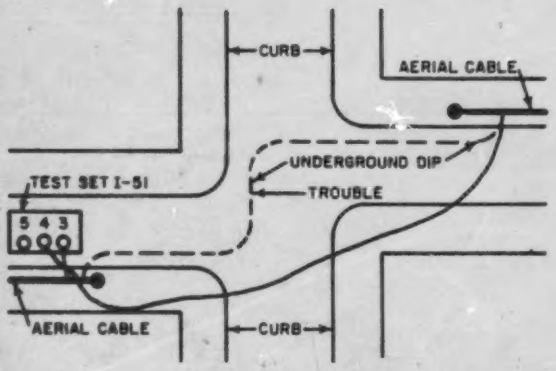
Stray Current Method of Tracing Conductor

In locating and tracing the path of a buried cable or a conductor which is not readily accessible, it is generally advisable first to attempt to make a location by the stray current method with the coil held in a horizontal position. Walk across the approximate path of the conductor to determine whether there is sufficient stray current flowing to give an audible signal or tone in the receivers. If there is, the tone volume will rise gradually to a maximum as the conductor is approached, suddenly fall to a low value when the coil is directly over the conductor, rise again to previous maximum as the conductor is passed, and then decrease slowly. If the exploring is done in the proximity of a powerline, most of the tone heard may be the result of induction from the line.

Tracing Conductor by Use of Test Set I-51

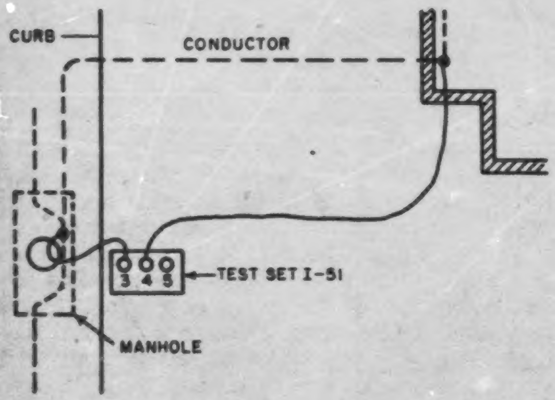
If there is too much disturbance from the powerline, or if the tone volume is inadequate, the stray current method will not be effective. Under such conditions the locating and tracing of a cable can generally be facilitated by using Test Set I-51 as a source of tracing current. The test set is placed as far as possible from the conductor at the point of tracing. The set may then be connected in any one of three ways, depending on the distance to be covered and the accessibility of the conductor to be located. Regardless of the method of construction, intermittent tone should be used in the set.

When the conductor to be traced is relatively short and is accessible at two points, as shown

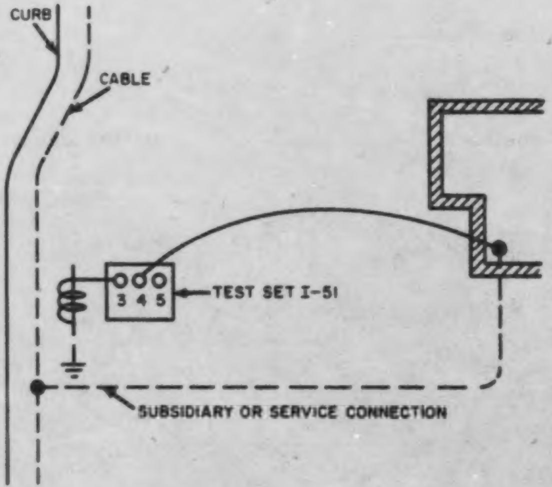


26.58
Figure 5-51.—Tracing buried cable conductor with test set I-51, underground dip.

in figures 5-51 and 5-52 (one on each side of the area in question), it is advisable to connect the set directly. The connection is made with insulated wires which are attached to terminals 3 and 4 of the set, and are placed on the ground in such a way that they will not parallel the conductor in the area where the location is made. Intermittent tone should be used.



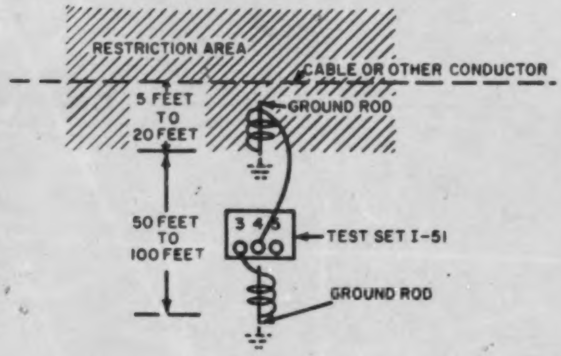
26.59
Figure 5-52.—Tracing cable conductor in underground subsidiary with test set I-51.



26.60
Figure 5-53.—Tracing accessible conductor with test set I-51 and one ground rod.

When the conductor to be traced is accessible at one point and the approximate location is known at another point, the tracing current can be applied as illustrated in figure 5-53. Install the ground rod 5 to 20 feet from the cable. Connect the set to the conductor and rod as described above, except that a number 3 bridging connector may be used to attach the lead to the rod.

If the conductor to be traced is not accessible and the approximate location is known, install one ground rod close to the conductor (5 to 20 feet), and another ground about 50 feet from the first ground rod and in a line approximately at right angles to the conductor (fig. 5-54). If the approximate location of the conductor is not known, the separation between the rods should be about 100 feet. If a powerline is in the vicinity of the conductor, place the rods on the powerline side of the conductor. Drive the rods approximately 2-1/2 feet into the earth; but where the soil is loosely packed or contains many small stones, drive the rods deeper, or move them to another location where the soil conditions are more favorable. If the separation between rods is not over 50 feet, make location tests at a point not less than 100 feet from the rods. Within this area a strong tone will be heard, but the location will not be reliable. Where the separation is more than 50 feet, the restricted area extends about 200 feet from the conductors.



26.61
Figure 5-54.—Tracing inaccessible conductor with test set I-51 and two ground rods.

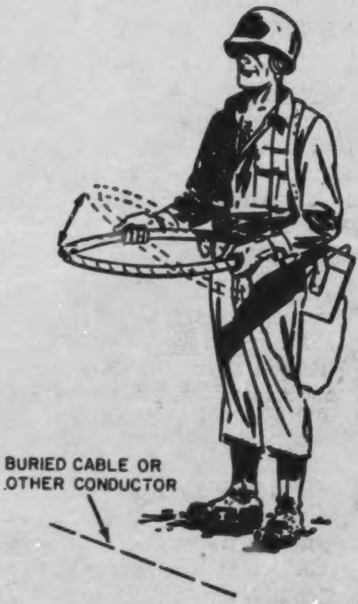
Locating Conductors

To locate conductors, stand at a point that is believed to be near the cable or conductor (on the side away from any powerline, if there is one nearby). Hold the exploring coil in a horizontal position and rock it slowly around a horizontal axis which is considered parallel to the conductor, as shown in figure 5-55, until a tone is heard. If no tone is heard, move to other positions in the general vicinity of the suspected location of the cable, until a tone is heard. This verifies the fact that you are in within 40 feet (approximately) of the cable. (See fig. 5-56.)

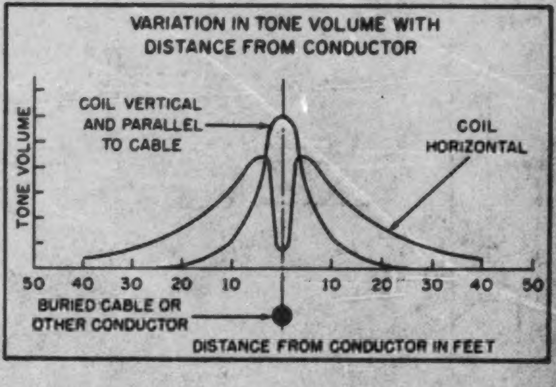
After the general location of the conductor has been determined, the following procedure is used to determine the exact location. Starting at the point where the tone is first heard and with the coil held in a horizontal position, the volume of the tone heard will rise gradually to a maximum as the conductor is approached (fig. 5-56), fall suddenly to a low value when the coil is directly over the buried conductor, rise again to the previous maximum as the conductor is passed, and then decrease slowly.

A further check on the direction of the cable run can then be made by holding the exploring coil in a vertical position and then rotating the coil around its vertical axis. When the tone is at a maximum, the plane of the coil is parallel to the conductor.

A check may be made by holding the coil in a vertical position, with the plane of the coil parallel to the conductor, and again walking across the conductor. The tone volume will rise


BURIED CABLE OR OTHER CONDUCTOR

26.62
Figure 5-55.—Getting general location of buried cable.



26.233
Figure 5-56.—Tone volume versus position of coil and distance from cable.

as the conductor is approached, reach a maximum directly over the conductor, and then decrease as the conductor is passed (fig. 5-56).

TELEPHONE TEST SET AN/PTM-5

Telephone test set AN/PTM-5 (fig. 5-57) is a portable, light-weight, battery-operated cable splicer's test set that will detect and amplify weak tone signals. The test set is used to identify single leads or pairs in a cable without breaking the individual conductor insulation. It can be used with either a test probe or an exploring coil.

The instrument consists of an AUDIOFREQUENCY AMPLIFIER, ELECTRICAL ASSEMBLY, HEADSET, belt clip, carrying strap, case, and associated spare parts (fig. 5-57).

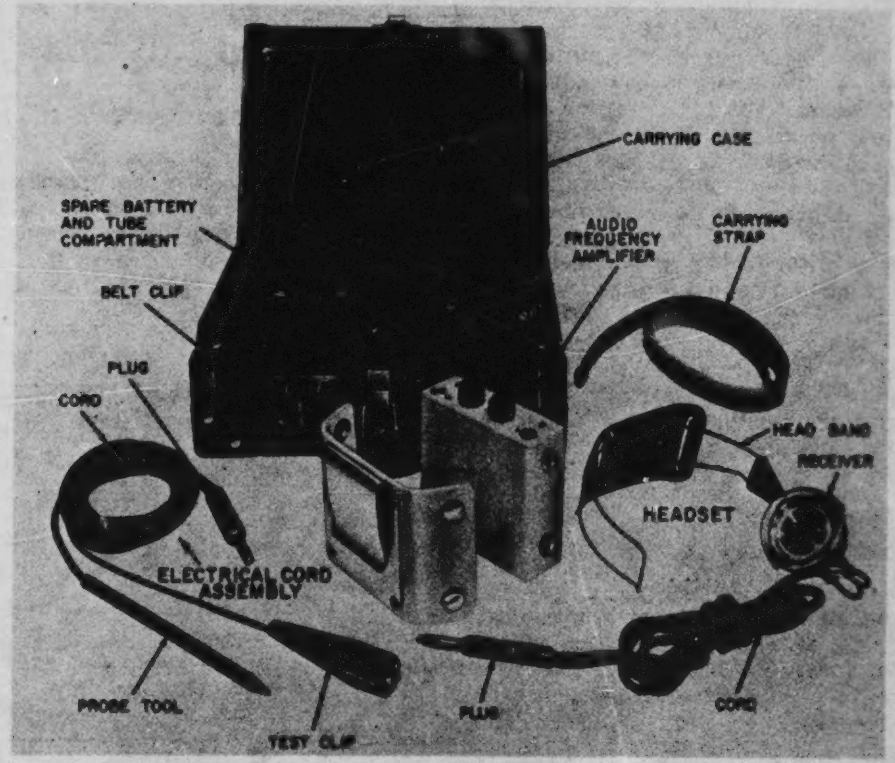
Additional Equipment Required

The following equipment is not supplied as part of the AN/PTM-5, but is required for all types of operation of the test set.

(1) One battery BA-261/U (22-1/2 volts).
(2) Two batteries BA-58 or one battery BA-272/U (1-1/2 volts).
(3) An audio oscillator with an output frequency of approximately 500 hertz is required as a tone source.

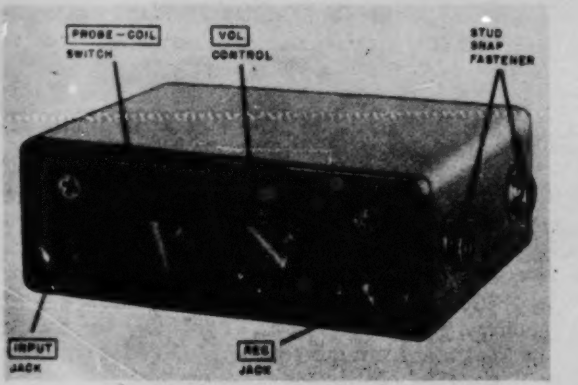
When the test is used with an exploring coil (such as Sig C stock no. 3F4316.2), the following additional equipment is required to connect the exploring coil to the test set:

(1) Cord (Sig C stock No. 3E8000-72.2).
(2) Plug (Federal stock No. 5935-192-4774).


CARRYING CASE
SPARE BATTERY AND TUBE COMPARTMENT
AUDIO FREQUENCY AMPLIFIER
CARRYING STRAP
BELT CLIP
PLUG
CORD
HEAD BAND
RECEIVER
HEADSET
ELECTRICAL CORD ASSEMBLY
PROBE TOOL
TEST CLIP
PLUG
CORD

73.284

Figure 5-57.—Telephone test set AN/PTM-5.


PROBE-COIL
SWITCH
VOL
CONTROL
STUD
SNAP
FASTENER
INPUT
JACK
REC
JACK

73.285
Figure 5-58.—Amplifier, front view.

Audiofrequency Amplifier AM-984/U

The AM-984/U (amplifier) is contained in a gray metal box. Operating controls (fig. 5-58) are mounted on the plastic front panel. A belt clip can be secured to the amplifier case by snap fasteners on each side of the amplifier case. The operating controls and jacks (fig. 5-58) perform the following functions. The INPUT jack connects a probe or exploring coil to the input of the amplifier. The REC (receive) jack connects the amplifier output to the headset. The PROBE-COIL switch, when turned to the PROBE position, connects the INPUT jack to the amplifier through a high impedance network. When it is in the COIL position, the INPUT jack is connected to the amplifier through a low impedance network. The VOL control adjusts the volume of the amplifier output from MINIMUM to MAXIMUM as it is adjusted from the range 0 to 100.

Electrical Cord Assembly CX-4158/U

The CX-4158/U (test probe) consists of a two-conductor test cord terminated in a switchboard-type plug at one end and a test clip and the probe tool at the other end. The probe tool consists of a blunt brass tip fastened to a fiber handle.

Headset H-147/U

The H-147/U (test receiver) consists of a telephone receiver mounted on a headband. It is equipped with a two-conductor cord terminated on a switchboard-type plug.

Operation

Connect a tone source to the cable in one of the three arrangements below, as applicable:

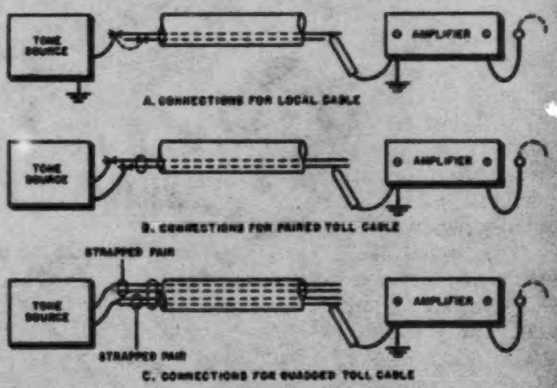
LOCAL CABLE OR CABLE NOT IN USE: Connect the tone source between one wire or a pair and ground (cable sheath) (fig. 5-59, view A).

PAIRED TOLL CABLE: Connect the tone source between the wires of a pair (fig. 5-59, view B).

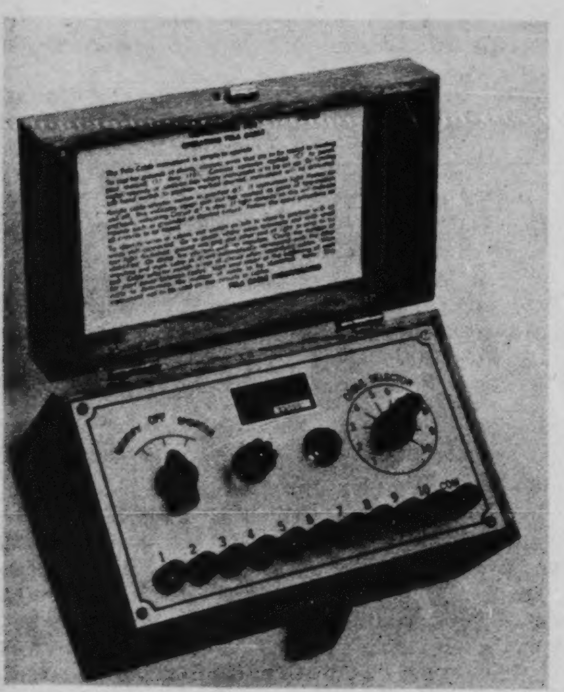
QUADDED CABLE: Strap the two wires to each pair in the quad together and connect the tone source between the two strapped pairs (fig. 5-59, view C).

If a section of the sheath has been removed from the cable, bond the two ends of the cable sheath together to prevent interference in the amplifier. Place the probe tip on the cable pairs at a right angle to the cable. DO NOT TOUCH THE PROBE TIP WITH THE FINGERS, AND DO NOT ALLOW THE TIP TO MAKE CONTACT WITH THE METALLIC CONDUCTOR.

Move the probe tip around the outside of the cable pairs to determine whether the wire to be located is in the outside layer. If the wire is in the outside layer, a loud tone should be heard. If no tone is heard, push the probe tip into the cable at various points until the loudest


TONE SOURCE
AMPLIFIER
A. CONNECTIONS FOR LOCAL CABLE
TONE SOURCE
AMPLIFIER
B. CONNECTIONS FOR PAIRED TOLL CABLE
STRAPPED PAIR
TONE SOURCE
AMPLIFIER
STRAPPED PAIR
C. CONNECTIONS FOR QUADDED TOLL CABLE

73.286
Figure 5-59.—Tone source connections.



73.287X
Figure 5-60.—Tela Cable Model 262.

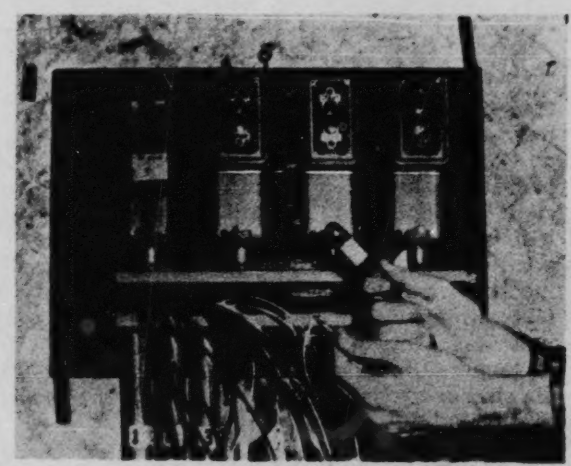
tone is heard. Then separate the pairs and test them individually.

TELA CABLE Model 262

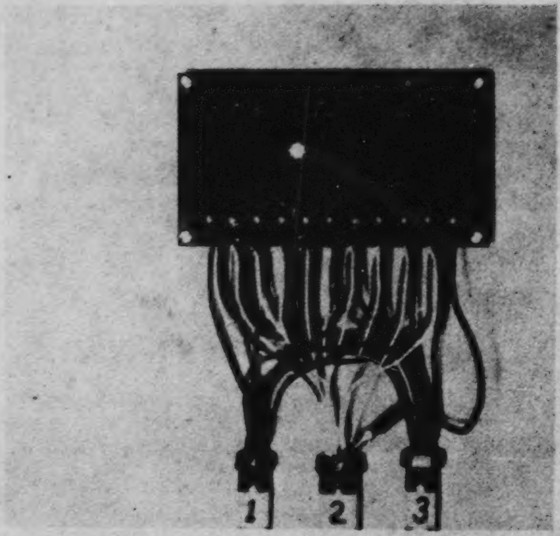
Tela Cable Model 262 (fig. 5-60) is a portable instrument which identifies cables and detects grounds, shorts and defects very quickly and simply. One advantage this instrument affords is that testing is accomplished by using one man rather than the time-tested method of using two men with an elaborate procedure of communications between the two.

The instrument sends out pulsating signals which are received by a test probe (fig. 5-61). The number of pulses seen visually identify each wire of a cable when appropriate hookup is made. Figure 5-62 illustrates how as many as 30 wires or cables can be checked using only the 10 binding posts on the instrument.

The procedure for using the instrument is simple. Connect the test lead from the terminal



73.288X
Figure 5-61.—Test probe.



73.289X
Figure 5-62.—Checking 30 wires with Tela Cable.

marked COM on the instrument panel to one of the following: conduit, metal raceway, shield wrapped around cable, or any other grounded equipment in the vicinity. Connect wires to be tested to binding posts 1 through 10.

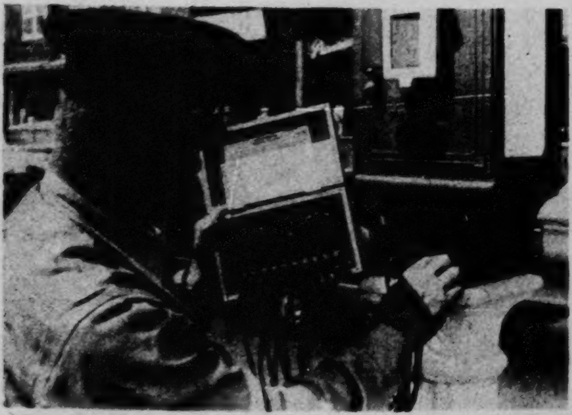
Check for Grounds

To check for grounds, turn the IDENTIFY-OFF-SHORTED switch (fig. 5-60) to position marked SHORTED. This turns the instrument on. Rotate the CABLE SELECTOR switch through positions 1 to 10.

If a GROUND is present, the indicating light will come on immediately and stay lighted. The position of the CABLE SELECTOR switch will identify what circuit or wire has the GROUND. If the instrument light flashes on and off, this indicates that the signal has reached its point of termination and returned safely without being shorted or grounded out.

Identifying Wires and Cables

To identify wires and cables, turn the IDENTIFY-OFF-SHORTED switch to IDENTIFY with the wires still connected to the instrument. This removes the CABLE SELECTOR switch from the circuitry. Go to the points where the wire is terminated. The small test light furnished (fig. 5-63) has two leads. Ground one lead to the metal raceway or equipment ground in the vicinity. Connect the other end of the light to the unidentified wire. When appropriate hookup is made, count the number of impulses being emitted. It will correspond with the numbers at the other end automatically. Mark or otherwise identify your cable.



73.290X
Figure 5-63.—Identifying wires and cables.

Wait for the short pause between cycles and then begin counting. This instrument must be used on dead circuits or cables only. Be sure that all power is removed from the cables to be checked before applying this instrument.

CARE OF INSTRUMENTS

The instruments which have been described are delicate precision instruments which must be protected from damage that would cause erratic or inaccurate readings. Replacements are not always available, and there is always delay when an instrument must be sent for shop overhaul or repair. Even more hazardous is the possibility that an instrument may be damaged, so as to cause inaccurate readings, without anyone being aware of the fact.

The accuracy of a-c instruments may be affected both mechanically and electrically. Mechanical factors include excessively high or low temperature, moisture, corrosion, dirt, vibration, shock, poor mechanical balance, and bending or warping of pointer or scale. Electrical factors include variations in voltage or frequency, variation in power factor, abnormal wave forms, electrostatic deflections, and (particularly) overloading.

Remember that the information given in this chapter is intended to help you to use these instruments to advantage and care for them properly—NOT to enable you to adjust or repair them. The case of an electrical measuring instrument, either switchboard-mounted or portable, must never be opened except by a qualified repairman. However, you are responsible for proper handling and maintenance.

CHAPTER 6

CONTROL AND PROTECTIVE EQUIPMENT

This chapter describes how and why control and protective devices are used. This knowledge will help you find the cause of interruption, clear the trouble, and restore operation safely with a minimum loss of time when vital electrical equipment is inoperative.

Control devices are those electrical accessories which govern, in some predetermined way, the power delivered to any electrical load. They may take the form of elementary mechanical switches or complicated electrical contactor devices.

Protective devices interrupt the power to circuits and equipment when circuit conditions become dangerous. Fuses, circuit breakers, reverse-current and power relays are protective devices.

Severe damage can occur to generators, electrical distribution systems, and equipment if control and protective devices do not perform satisfactorily. Since an important part of your job is to maintain uninterrupted operation of equipment, you can see how knowledge of the purpose, construction, operation and testing of protective and control devices will enable you to keep equipment operational.

PROTECTIVE DEVICES

The simplest protective device is a fuse. Review Basic Electricity, NAVPERS 10086-B for clarification of the basic fuse types. We will discuss practical tests and techniques for locating a variety of possible troubles in fused circuits and other protective equipment and the measures taken to correct them.

TROUBLESHOOTING SECONDARY FUSED CIRCUITS

An electrical system may consist of a comparatively small number of circuits. In larger systems, the installation may be equal to that of a fair sized city.

From the main power supply, total electrical load is divided into several feeder circuits, and each feeder circuit is further divided into several branch circuits. Each feeder and branch circuit is fused individually to safely carry its own load. This minimizes the possibility of one circuit failure interrupting the power for the entire system.

When trouble occurs, a systematic procedure will enable you to isolate and correct GROUNDED, SHORT, AND OPEN circuits safely and in a short period of time.

A grounded circuit occurs when current flows from a hot conductor to a metallic conduit system, any grounded surface, or earth.

A short circuit exists when two or more conductors come into contact with one another because of improper wiring or breakdown of insulation.

Application of voltage to either of the above circuits will cause fuses to blow if the current ratings of the fuses are exceeded.

An open circuit exists when there is a break in the continuity of the circuit. An undesired open circuit is generally found in junction boxes or equipment terminals. They are caused either by splices coming apart from vibration, or when screws become loose from expansion and contraction caused by changes in current flow.

Suppose a fuse blows in a 110-volt circuit with a grounded neutral. It might have been the result of overloading the circuit. But suppose a new fuse is installed, and it, too, blows. In most cases this means that a short or ground is causing the trouble. Also, if the trouble is an overload, the fuse will heat gradually and then blow, but a short or ground will cause it to blow instantly.

A visual inspection of the defective circuit will often reveal the difficulty. Perhaps some equipment has been pushed against the line, or smoke or sparks were seen coming from a box just before the fuse burned. If inspection and questioning of personnel cannot pinpoint the trouble, you must "dig into" the circuit with systematic tracing.

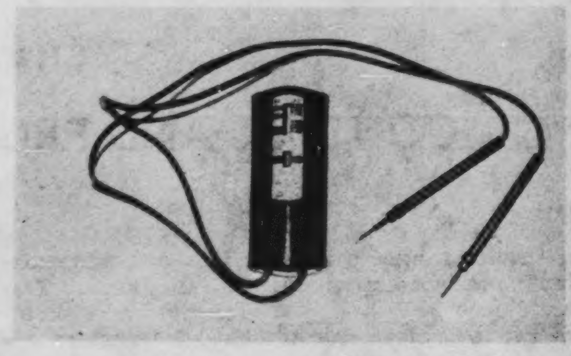
Let's take a typical branch circuit for lighting or convenience outlets, consisting of two wires, a black (hot) wire and a white (neutral) wire. Normally, the current will pass through each fixture and appliance connected to the circuit. When it fails to do so, your first thought should be that there is an opening somewhere in the circuit between the panelboard and the fixture or appliance which fails to function. Essentially, all you have to do is trace the wires systematically, starting at the last point where you do have voltage, until you find the opening.

There are several types of testing devices you can use to check for a ground or short, but the Wiggins type voltage indicator shown in figure 6-1 is one of the best.

To locate the trouble, first open the switch, remove the fuse, remove all appliance cords and lamps from the circuit, and disconnect the black and white wires from the source of power. Then replace the fuse and close the switch. Now touch one lead of the tester to power source and the other lead to the black wire. If you get a reading on the voltage tester the trouble is a ground in the circuit. If you get no reading, you will probably find that you have a short. This situation is illustrated in figure 6-2, view A.

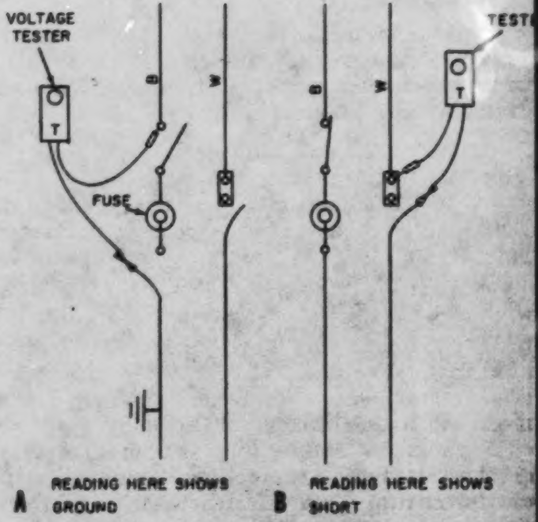
Recheck for a short by connecting the black wire to the power source and test from white wire to ground connection with the tester as shown in figure 6-2, view B. A reading here will verify that you have a short. If you don't get a reading, start replacing the wires, one at a time, and test after replacing each until you do get a reading. You will then know which wire is causing the trouble.

If you have plug fuses in the switch or panel, another way to test is to remove the fuse where the trouble is and replace it with a 100-watt lamp. If there is a short or ground in the circuit the lamp will burn. If it continues to burn with all cords and lamps removed, open the circuit about the middle and test. This cuts your area of search in half, and by this



73.32

Figure 6-1.—Voltage indicator.



73.34

Figure 6-2.—Checking for (A) Ground; (B) Short.

process of elimination you can trace the trouble to its source.

Use the greatest caution when checking wires in boxes. BEFORE YOU DISCONNECT OR CONNECT ANY WIRE, BE SURE THE CIRCUIT IS DEAD.

Open the switch first, then remove the fuse or fuses. When disconnecting wires, always disconnect the hot wire or wires first. When reconnecting, always connect the neutral first and the hot wire or wires last.

You will often find that the cause of a short or ground was careless taping of wires by the men who wired the building. Remember this when you are wiring a building yourself, and do your taping properly so that some other Construction Electrician will not have to locate trouble caused by your carelessness.

HIGH-VOLTAGE FUSES

High-voltage fuses are used to protect transformers and transmission lines against shorts, grounds and overloads. For substations up to the 69-kv class having transformer capacity limited to 5,000 kva or less, fuses combined with gang-operated airbreak switches are safe and reliable and may be used for transformer protection regardless of the location of the transformer (pole top, platform, and so on). They are also used throughout the system for branch or spur line protection. Fuses and airbreak switches are more economical to install and maintain than oil circuit breakers. The added maintenance cost of replacing fuses is more than recovered in reduction of costs chargeable to inspection and maintenance of oil circuit breakers, relays, and battery control circuits. One disadvantage of fuses in three-phase connections is that they may single-phase. Single-phasing may cause a three-phase motor to burn out. There is no possibility of single-phasing with an oil circuit breaker.

When refusing gang-operated airbreak switches, greater safety is ensured with the installation of a gang-operated grounding device that grounds both sides of the fuse. If such a device is not warranted, ordinary ground sticks should be accessible for use at all times.

A fusing platform may be used to enable the operator to replace fuses that are mounted too high in the structure or too close to high-voltage equipment for safe fuse-stick operation from the ground.

Expulsion Type Fuses

The expulsion fuse shown in figure 6-3 is an open cutout or disconnect fuse. It has a universal tension type fuse link internally. When the fuse link melts, current is made to flow through the thin stranded wire. The current instantly melts the wire and allows the spring to separate the fuse terminals (fig. 6-4).

Repeating Cutout Fuses

The repeating cutout fuse shown in figure 6-5 has three fuse tubes mounted so that when

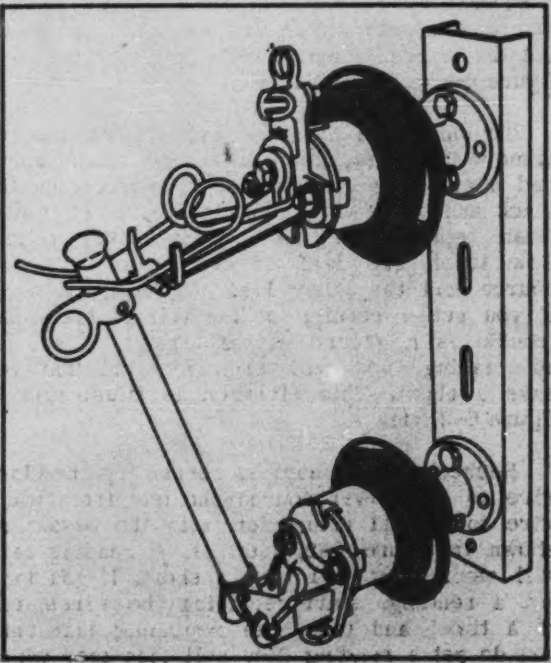
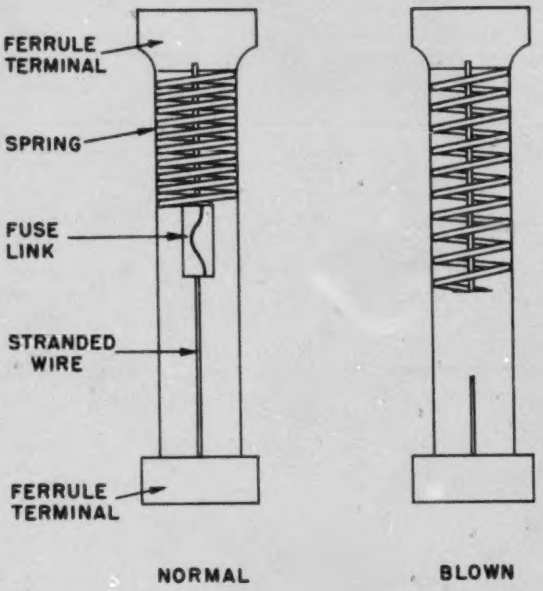
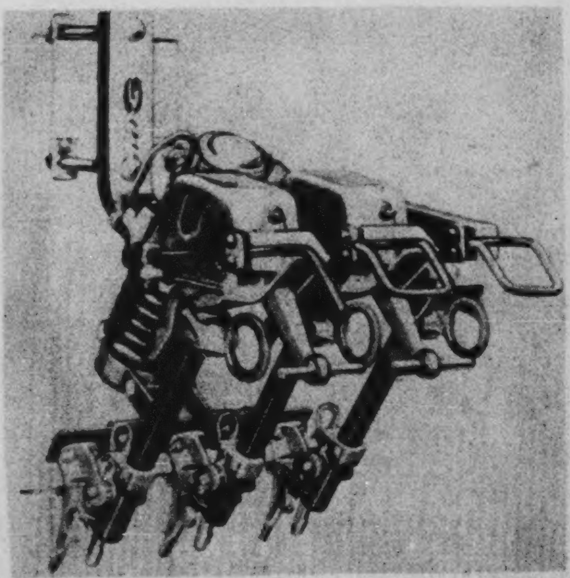


Figure 6-3.—Outdoor open type cutout fuse (expulsion), 7,500 volts, 100 amperes.



26.212
Figure 6-4.—Representative expulsion fuse before and after blowing.



26.8
Figure 6-5.—Automatic reset repeating cutout fuse, 15,000 volts, 100 amperes.

the first fuse blows, it trips the second fuse into the circuit. If the fault continues, the second fuse trips in the third. This arrangement allows clearance of temporary faults and promptly restores service by the automatic circuit reclosing action of the second and third fuse, if necessary. This type of fuse assembly is almost exclusively applied in outdoor distribution circuits.

OTHER FUSES

Other types of fuses are the BORIC ACID FUSES, LIQUID FUSES, and DRY TYPE CURRENT-LIMITING FUSES. In the boric acid fuse, a malfunction in the circuit produces steam which interrupts the flow of current. This type of fuse can be mounted with small clearances; there is no visual indication that the boric acid fuse has blown.

One common form of liquid fuse is the oil-filled cutout, in which the fusible element is submerged in oil and is generally mounted on a circulating or rotating frame so that by moving an external handle the circuit can be interrupted. This type of fuse is generally used in underground systems.

There are two kinds of dry type current-limiting fuses: the single and the double element type. These fuses operate on the principal of melting the fuse far in advance of the possible peak current of the first half-cycle. The fuse is designed in such a manner that the melting process introduces a high arc resistance, which, in turn, holds the circuit current within the rating of the fuse.

FUSE MAINTENANCE

Fuses must be kept tight in their clips to ensure good contact and to avoid air gaps. An air gap between a fuse and its clip will allow oxidation when heated by current passing through the fuse. If a fuse clip or contact is allowed to oxidize to the point where it presents a high resistance to current flow, the fuse may become worthless. The resistance of the oxidized fuse contact or clip is in series with the fuse and will defeat the purpose of the fuse entirely if the oxidation is not removed. If the fuse does not make proper contact, it will either drop excessive voltage and impede the current flow or present an infinite resistance. Improper fuse contact will impair or even prevent operation of otherwise normal equipment. To prevent equipment failures caused by faulty fuses, the following precautions should be observed:

1. Tight contact must be made between fuse and clip to prevent oxidation.
2. If oxidation is noted, it should be removed by fine sandpaper or light filing, and the clips should be readjusted to fit tightly against the fuse.

When a fuse or fuse element blows, care must be taken to replace it with a properly rated fuse or element. An improper replacement will either damage the equipment or curtail its operation. If the washer or end ring on a renewable fuse is burned or partially melted, it indicates that the cap was not screwed on tightly. Charring of the fiber tube or inside fiber strip in a renewable fuse always indicates poor contact or overfusing. Overfusing is defined as installing a renewable link of greater capacity than called for. Poor contact is to be especially avoided as the heat produced by the current flowing through this contact is conducted to the fuse, melting the link prematurely or damaging the case.

Fuse maintenance also involves inspecting mountings and supports, and checking for broken insulators and mechanical defects. Replace broken or cracked insulators without delay and repair or replace, as necessary, other parts that are defective. Routine inspections should always include:

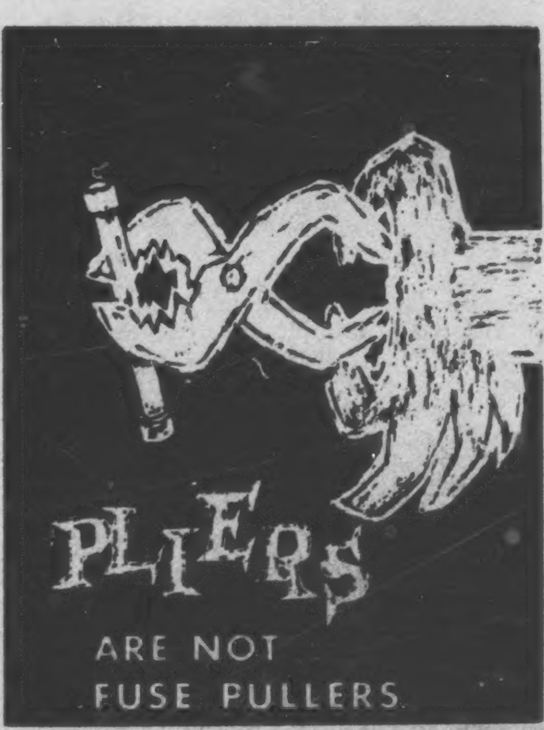
1. Checking fuses for correct rating and ensuring that fuse tubes are capped securely to exclude dust and water.
2. Replacing warped, broken, scorched, or burned tubes.
3. Keeping fuses with dropout and repeating features in good condition and free from foreign matter, and checking them for proper operation by trial on routing fuse changes, or when the transformer bank is deenergized for other purposes.

SAFETY WITH FUSES

Design features for fuse safety are incorporated in Military Standards and Specifications such as MIL-F-15150. To eliminate fuse safety hazards, follow these rules:

1. Do not short out fuses.
2. Use fuse pullers, not pliers (fig. 6-6).
3. Always deenergize circuits prior to removing fuses.
4. Ensure that replacement fuses and links are of correct amperage.

If an attempt is made to make a fuse carry a current greater than that for which it was designed, the terminals and current-carrying parts of the fuse will overheat, damaging the fuse case and taking the spring tension out of the fuse clips. Furthermore, a renewable fuse that is overfused may explode if subjected to a heavy short circuit. The pressure developed by the volatilization of the extra metal will be greater than the fuse case was designed to handle. Drilling holes in the sides of a fuse tube to keep down the temperature makes a monstrous hazard because a fuse



40.67
Figure 6-6.—Use fuse pullers, not pliers, to remove fuses.

with holes explodes more readily than a totally enclosed fuse. Pressure inside the fuse case helps to extinguish the arc when totally enclosed. Furthermore, such holes also permit the expulsion of molten metal and hot vapors which may ignite flammable material and cause serious burns.

CIRCUIT BREAKERS

Circuit breakers are generally used at substations and at junction points of important circuit or lines to switch transformers in or out of circuits and to sectionalize lines.

Circuit breakers, like fuses, automatically open the circuit whenever the current exceeds a predetermined value, because of either a fault or an overload in the circuit. After being tripped open, the circuit may be closed manually or may be automatically reclosed after a short delay.

There are two general types of circuit breakers: the air circuit breaker and the oil circuit breaker.

AIR CIRCUIT BREAKERS

Air circuit breakers are so called because the main contacts open in the air. Air circuit breakers are normally used on switchboards, switchgear groups, and distribution panels. They are seldom, if ever, used on distribution lines. When operated electrically, the operation is usually in conjunction with a pilot device such as a pressure switch. Electrically operated circuit breakers use an electromagnet which acts as a solenoid to trip a release mechanism that causes the breaker contacts to open. The energy to open the breaker is derived from a coiled spring. The electromagnet is controlled by the contacts of the pilot device.

Circuit breakers designed for high currents have a double-contact arrangement. The complete contact assembly consists of the main bridging contacts and the arcing contacts. All current-carrying contacts are high-conductivity, arc-resisting silver or silver alloy inserts.

Each contact assembly has a means of holding the arcing to a minimum and extinguishing the arc as soon as possible. The arc control section is called an arc chute or arc runner. The contacts are arranged so that when the circuit is closed, the arcing contacts close first. Proper pressure is maintained by springs to ensure that the arc contacts close first and that the main contacts follow.

When the circuit opens, the main contacts open first. The current then flows through the arc contacts; this prevents burning of the main contacts. When the arc contacts open, they pass under the front of the arc runner. This causes a magnetic field to be set up, which blows the arc up into the arc quencher and quickly opens the circuit.

ACB Breaker

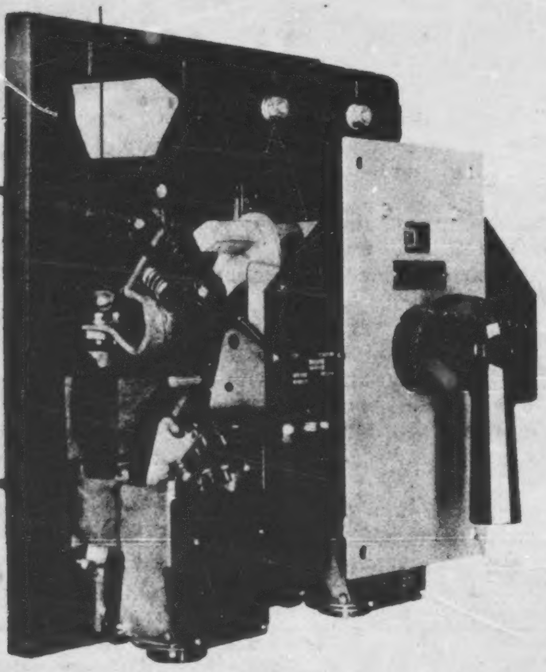
The ACB type of circuit breaker may be used for either manual local closing or electrical remote closing. It has an open metallic frame construction mounted on a drawout mechanism and is normally applied where heavy loads and high short circuit currents are available.

Figure 6-7 shows the external appearance of a type ACB circuit breaker.

Type ACB circuit breakers are divided into manually and electrically operated types. The only difference is that the manually operated types must be operated by hand. However, all ACB circuit breakers may be operated electrically if the magnet and armature mechanism is installed. The heavy-duty types are electrically operated because it is then unnecessary for personnel to approach them in order to open or close the circuit.

NO CIRCUIT BREAKER, REGARDLESS OF TYPE, SHOULD BE WORKED ON WITHOUT OPENING THE CIRCUIT. Remember that certain terminals may have voltage applied to them even though the breaker is open.

When used in these applications the pilot device may be a reverse-power relay or any of the control devices discussed later in this chapter of the training manual. The reverse-power relay is mounted on the panel close to the circuit breaker. Other automatic controls may be located at remote points to give maximum protection to the circuit.



27.73

Figure 6-7.—ACB circuit breaker.

Maintenance

Metal locking devices are available that can be attached to the handles of a circuit breaker to prevent accidental operation. All breaker handles are now provided with a 3/32-inch hole which allows the locking device to be fastened with a standard cotter pin.

No work should be undertaken on circuit breakers without first obtaining the approval of the proper authority (usually the Safety Officer).

Circuit breakers require careful inspection and cleaning at least once a year (more frequently if subjected to unusually severe service conditions).

Before working on a circuit breaker be aware of its time-delay characteristics, whether short time, long time, or instantaneous tripping time is required. The adjustments that produce selective tripping of the circuit breakers are made and sealed at the factory; no unauthorized changes should be made to their trip settings because these changes may completely disrupt the protective function for which they were designed. Improper tripping action is corrected best by replacement of the entire breaker assembly, especially where trouble is encountered in the compact assemblies.

A special inspection should be carefully made of each pair of contacts after a circuit breaker has opened on a heavy short circuit. Before working on a circuit breaker, deenergize all control circuits to which it is connected; the procedure differs somewhat with the type of mounting which is employed. For example, before work is performed on drawout circuit breakers, they should be switched to the open position and removed. Before working on fixed-mounted circuit breakers, open the disconnecting switches ahead of the breakers. If disconnecting switches are not provided for isolating fixed-mounted circuit breakers, deenergize the supply bus to the circuit breaker, if practicable, before inspecting, adjusting, replacing parts, or doing any work on the circuit breaker.

Contacts are the small metal parts especially selected to resist deterioration and wear from the inherent arcing. The arcing occurs in a circuit breaker while its contacts are opening and carrying current at the same time. When firmly closed, the contacts must not arc.

Contact materials have been subjected to constant research, resulting in various products, ranging from pure carbon or copper, to pure silver, each being used alone and also as alloys with other substances. Modern circuit breakers have contacts made of pure silver, or pure silver mixed with cadmium oxide, or pure silver and tungsten. The two latter silver alloys are extremely hard and resist being filed. Fortunately, such contacts made of silver or its alloys conduct current when discolored (blackened during arcing) with silver oxide. The blackened condition, therefore, requires no filing, polishing, or removal. As with a pure silver contact, silver oxide is formed during arcing and it has been found that the addition of cadmium oxide greatly improves operation of the contact because it minimizes the tendency of one contact to weld to another, retards heavy transfer of one material to another, and inhibits erosion.

Usually, a contact containing silver is serviceable as long as the total thickness worn away is between 0.015 and 0.030 inch.

Severe pitting or burning of a silver contact is another matter. It may require some fine sandpaper (No. 00) to remove raised places on surfaces that prevent intimate and and overall closure of the contact surfaces. If necessary, use a CLEAN cloth moistened with INHIBITED methyl chloroform. Be very certain to provide ample ventilation to remove all DEADLY and TOXIC fumes of the solvent.

When cleaning and dressing copper contacts, maintain the original shape of each contact surface and remove as little copper metal as possible. Inspect and wipe the copper contact surfaces for removal of the black copper-oxide film and, in extreme cases, dress and clean only with fine (No.00) sandpaper to prevent scratching the surfaces. (To avoid scratches, NEVER use emery cloth or emery paper.) Because this copper oxide film is a partial insulator, follow the sanding procedure by wiping with a clean cloth moistened with inhibited methyl chloroform solvent. Provide VERY LIBERAL ventilation by means of exhaust fans or with portable blowers to entirely remove all traces of the deadly fumes of the solvent.

The function of arcing contacts is not necessarily impaired by surface roughness. Remove excessively rough spots with a fine file. Replace arcing contacts when they have been burned severely and cannot be properly adjusted. Make a contact impression and check the spring pressure in accordance with the manufacturer's instructions. If information on the correct contact pressure is not available, the contact pressure should be checked with that of similar contacts. When the force is less than the designed value, the contacts either require replacing because they are worn down, or the contact springs should be replaced. Always replace contacts and contact springs in sets, not singly; replace contact screws at the same time. Do not use emery paper or emery cloth to clean contacts, and do not clean contacts when the equipment is energized.

Clean all surfaces of the circuit breaker mechanism, particularly the insulation surfaces, with a dry cloth or airhose. Before directing the air on the breaker, be certain that the water is blown out of the hose, that the air is dry, and that the pressure is not over 30 psi. Check the pins, bearings, latches, and all contact and mechanism springs for excessive wear or corrosion and evidence of overheating. Replace parts if necessary.

Slowly open and close circuit breakers manually a few times to be certain that trip shafts, toggle linkages, latches, and all other mechanical parts operate freely and without binding. Be certain that the arcing contacts make before, and break after, the main contacts. If poor alignment, sluggishness, or other abnormal conditions are noted, adjust in accordance with the manufacturer's instructions for the particular circuit breaker.

Oil-piston type overcurrent tripping devices (grade B timers) are sealed mechanisms and normally do not require any attention. When oil-film (dashpot) overcurrent tripping devices are used, the oil should be removed and the interior of the oil chambers should be cleaned with kerosene and refilled with new oil every 6 months. Be certain that the dashpot is free of dirt, which destroys the time-delay effect, and that the tripping device is clean, operates freely, and has sufficient travel to trip the breaker. Do not change the air-gap setting of the moving armature, because this would alter the calibration of the tripping device. Lubricate the bearing points and bearing surfaces (including latches) with a drop or two of light machine oil. Wipe off any excess oil.

Before returning a circuit breaker to service, inspect all mechanical and electrical connections, including mounting bolts and screws, drawout disconnect devices, and control wiring. Tighten where necessary. Give the breaker a final cleaning with a cloth or compressed air. Operate manually to be certain that all moving parts function freely. Check the insulation resistance.

The sealing surfaces of circuit-breaker contactor and relay magnets should be kept clean and free from rust. Rust on the sealing surface decreases the contact force and may result in overheating of the contact tips. Loud humming or chattering will frequently warn of this condition. A light machine oil wiped sparingly on the sealing surfaces of the contactor magnet will aid in preventing rust.

Oil should always be used sparingly on circuit breakers, contactors, motor controllers, relays, and other control equipment, and should not be used at all unless called for in the manufacturer's instructions or unless oil holes are provided. If working surfaces or bearings show signs of rust, disassemble the device and carefully clean the rusted surfaces. Light oil can be wiped on sparingly to prevent further rusting. Oil has a tendency to accumulate dust and grit, which may cause unsatisfactory operation of the device, particularly if the device is delicately balanced.

Arc chutes or boxes should be cleaned by scraping with a file if wiping with a cloth is not sufficient. Replace with new linings when they are broken or burned too deeply. Be certain that arc chutes are securely fastened and that there is sufficient clearance to ensure that no interference occurs when the switch or contact is opened or closed.

Shunts and flexible connectors, which are flexed by the motion of moving parts, should be replaced when worn, broken, or frayed.

Operating tests that consist of operating the circuit breakers in the manner in which they are intended to function in service should be conducted regularly. For manually operated circuit breakers, simply open and close the breaker to check the mechanical operation. To check both the mechanical operation and the control wiring, electrically operated circuit breakers should be tested by means of the operating switch or control. Exercise care not to disrupt any electric power supply that is vital to the operation of the station, or to endanger personnel by inadvertently starting motors and energizing equipment under repair.

OIL CIRCUIT BREAKERS

A representative oil circuit breaker consists of one or more metal tanks filled with insulating oil, and metal caps attached to the top of the insulating bushings. Conductors or copper rods attached to stationary contacts located below the oil level in the tanks pass through the metal caps. The stationary contacts are bridged by movable contacts. The movable contacts are operated by an external or an internal source. When the breaker is closed, the movable contacts complete the circuit; when the circuit is open, they are displaced from the bridging position.

Installation

Circuit breakers are normally mounted and controlled in one of the following ways:

1. Directly on a switchboard with manual closing and opening and with automatic electrical tripping.
2. Physically removed from a switchboard with manual closing and opening and with automatic electrical tripping.
3. Physically removed from a switchboard with electrical closing and opening and with automatic electrical tripping.

Closing mechanisms are of the solenoid type, the centrifugal-motor type, or the pneumatic type.

Energy for opening and closing oil circuit breakers, operated manually or by automatic remote control, may be supplied from one or more sources.

Maintenance and Inspection of Power Circuit Breakers

Procedures for inspecting and overhauling oil circuit breakers depend largely on the nature of service and the type of apparatus used. Make inspections at least twice a year and more often if necessary. Where a humid-tropical climate exists and a circuit breaker normally remains in an open or closed position over extended periods of time, operate it periodically for two or three opening and closing cycles to make sure that parts are in working order and properly lubricated. Such tests can usually be made at times when intermittent interruptions of power will not interfere with normal operation; make them during periods of light load if the breaker is in normally closed service for extended periods. Make an inspection after a breaker has opened to clear a severe fault. OVERHAUL AT LEAST EVERY 2 YEARS, preferably in the spring of the year. Recommended safety and other procedures for making periodic overhauls are described in the following paragraphs.

Safety

Two important safety rules are:

1. Make no adjustment or replacement of parts of circuit breakers without consulting the manufacturer's instruction manual first.
2. Place suitable barriers of rope or net with danger flags or signs around adjacent apparatus that might still be energized, thus preventing accidental contact by personnel.

An important procedure to follow BEFORE any work is done on any circuit breaker is to be sure that ALL CONTROL CIRCUITS to the circuit breaker are DEENERGIZED and ALL ISOLATING SWITCHES OPENED. Any disconnecting switches between the source and the circuit breakers must not be opened until after the circuit breaker has been tripped to the OPEN position. No work should be done on the opened circuit breaker until all isolating switches protecting it have been opened.

Make arrangements with the electrical supervisor to take the apparatus out of service. The man in charge of the crew must check to be sure the apparatus is deenergized, properly grounded, and safe to handle. He can accomplish this by making sure that all disconnect switches are opened to isolate the circuit breaker from any source of energy. CE's must be sure that the breaker cannot be opened or closed automatically by inadvertent operation of a remote control station. If there is no switch in operating control stations, the closing relays must be blocked in the OPEN position and; as a further protection, the trip-coils disconnected from the circuit and proper tags placed on the controls. In addition, the fuses on the primaries of the potential transformers on the oil circuit breaker side of the disconnecting switches should be removed for double valve protection.

Grounding can be performed safely by using rubber gloves, safety goggles, and a suitable grounding cable (fig. 6-8). This grounding cable should be #2 AWG or larger and have a suitable clamp on one end for making connections to a ground bus. On the other end, hot stick clamps should be provided for connection to the metallic terminals of the apparatus.

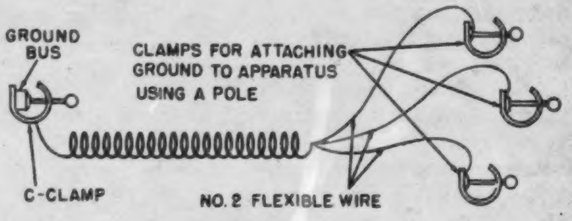


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Figure 6-8.—Grounding cable.

Testing and grounding is then accomplished by:

1. Connecting one end of an insulated test wire to the ground bus and fastening the other end to the disconnect pole.
2. Touching each metallic terminal of the bushing with a test cord (wear rubber gloves and goggles), and removing after touch-testing the apparatus.
3. Connecting the end of each grounding cable to the ground bus, and applying the hot stick clamps on the other end of the cable to each metallic terminal of the bushings of the oil circuit breaker.

Good safety practices PROHIBIT THE REMOVAL OF SWITCHING OR GROUNDING TAGS WITHOUT THE KNOWLEDGE AND CONSENT OF THE INDIVIDUAL WHO POSTED THEM. This safety practice MUST NEVER BE VIOLATED.

Additionally, use only one hand, keeping the other hand clear. Make sure you do not touch any parts other than the breaker operating handles since metal parts of circuit breakers may be at circuit potential. TRIP CIRCUIT BREAKERS BEFORE OPENING SWITCHES. Remember, too, that a circuit breaker must not be prevented from performing its normal function by short circuiting, blocking out interlocks, overload, or other protective devices except for the purposes of authorized test work.

Lowering and Removing Tanks

Place a pan under the breaker before lowering the tank, to catch any oil spill. Larger breakers usually have tank lifters for lowering the tanks; on smaller breakers, the tanks are lowered by hand. When using a tank lifter, take some tension on the lifting cables or platform to take the load off the bolts while they are being removed. Then remove the tank bolts and lower the tank to the pan on the floor or pad. When the tanks have been lowered, the following routine is recommended. Allow the mechanisms to drain for a few minutes before removing the tanks, and operate the breaker by hand to force oil out of the contacts. Do not trip free unless the contact mechanism is immersed in oil; this prevents injury to buffer springs, insulators, and so on. Release the breaker and let it out slowly by the hand-operating lever. After this has been done, wipe the interiors of the mechanisms dry with lint-free wiping rags. Then remove the tanks from beneath the breaker and filter the oil.

Tank Liners

The next step is to drain the tanks and remove the liners. Clean the tanks and liners with lint-free rags. If the liners are of the paper-composition type, check them carefully for moisture. Although paper liners do not absorb oil, they readily absorb any water that gets into the oil and ultimately cause the liners to separate and become soft and pliable. If a liner contains moisture, dry it in an oven before replacing it in the tank. If a liner has a metal ring around the top, check the bonding between the metal ring and tank. The ring must make positive contact with the tank metal.

Inspection of Contacts

Check contacts and arc tips for burning, mechanical and other defects. Although the main contacts should not show signs of burning, an arc sometimes carries over from the arc tips to the main contacts during a violent tripout. Check to see that breaker contacts are properly aligned and that contact surfaces bear against one another, with uniform, firm pressure and are adjusted in accordance with the instruction book. Replace badly pitted or burnt-out contacts, but smooth down with a clean fine file those that are only roughened. (This does not apply to silver contacts.) When a device contains both main and arcing contacts, the main contacts require little maintenance, but should be inspected regularly and kept smooth and clean.

Replace arcing contacts if they are badly pitted or burned or when their dimensions fall below minimum requirements. This will provide continuous protection to the main contacts from arc damage. Finger type contacts normally require more maintenance than butt contacts. An indication of excessive arcing is the decrease in thickness of the contact metal below the minimum thickness required for proper operation as stated in the instruction book. Most manufacturers state the minimum thickness of metal required for proper operation. Although some adjustment is provided, there are limitations beyond which operation will not be satisfactory.

Contacts on interrupters, such as those used on certain oil-blast breakers, require proper alignment and uniform pressure.

Radial-blast interrupters and cross-blast interrupters use butt contacts, with their arcing and current-carrying functions being performed by the same set of contacts. These are high-pressure type interrupters, and it is not necessary to dress or smooth their contact surfaces. Such contacts are gradually burned away by arcing however, and must be adjusted at intervals and replaced eventually to maintain proper contact. Approximately 3/32 of an inch can be burned off the upper and intermediate contacts before they demand replacement. The contact rod tip can be burned off to a stub too short to make contact without encroaching on required clearance between the bottom of the interrupter and the contact crossarm.

The main contacts of cross-blast interrupters require little attention except periodic checks for proper alignment and adjustment and to assure that they are kept smooth and clean.

Replace arcing contacts as in any other interrupting device when they become badly pitted or burned. Keep the contacts of magnetic air-blast breakers clean and bearing with uniform pressure in the same way as other contact surfaces. When proper contacts cannot be maintained, or the alloy turns back far enough so that the arc is destroying the copper, replace the contacts. In air-blast breakers, make periodic inspections to ascertain that no excessive wearing or scoring has taken place on the surfaces of the wiping contacts. If they are badly scored or pitted, replace them. A good indication of the condition of the contacts within the arc chute can be made by inspecting the arcing tips on the moving contact blades. If these are badly pitted or burned, it is probable that the internal contacts are in the same condition. Severely burned contacts or fibers in the chute indicate need of replacement.

Oil

Test oil in service at frequent intervals (3-month intervals are recommended) or after each operation at or near breaker rating. If oil shows signs of moisture, carbonization, or dirt, filter and test it with a standard spark gap oil tester. If the dielectric strength of the oil tests less than 22,000 volts as measured by standard disks in the tester spaced 0.1 inch apart, keep filtering the oil until the proper dielectric strength is reached. The dielectric strength of new oil should be 26,000 volts minimum. Keep the oil in the tanks at the proper level, and check the oil gage to make certain that it is indicating properly. Check all oil valves to see that they do not leak. Also, check the condition of all gaskets to make sure that they seal properly to prevent entrance of moisture and leakage of oil.

Bushings

Clean the external surfaces of bushings to remove dirt or other deposits. Where abnormal conditions prevail, clean bushings frequently to reduce possibility of flashover. Warm water and soap are recommended for cleaning most bushings; if soap is not available, an approved Navy solvent may be used; take care to avoid spilling the solvent on parts that could be injured by it. Check the bushings to make sure that they have not moved from the proper positions on account of vibration or other causes. Check porcelains for cracks or breakage, and note the level of oil in oil-filled bushings to make sure that it is at the proper level.

Internal Insulating Parts

Clean all surfaces of bushings and other insulating parts inside the tanks to remove traces of carbon or sludge that may remain after the tanks have been drained. Clean all internal parts of breakers before new filtered oil is added.

Keep insulating parts of nagnetic air-blast breakers clean and dry. Wipe off dust, carbon, or other foreign matter collected on magnetic air-blast breakers between inspection periods and, if there is evidence of dampness, install heaters in the compartment to ensure dryness. Scale that develops on the insides of arc chutes should be left intact, but loose scale in the muffler portions of the devices should be cleaned out to prevent malfunction of the arc.

Porcelain air-line insulators (if any) in the rear of the arc chutes in air circuit breakers should be wiped out and inspected for mechanical damage. Remove these insulators at least once a year and inspect for damage; then clean them internally with suitable solvents. Remove any accumulation of carbon or dirt.

Breaker Mechanisms

The breaker mechanism should operate smoothly and freely without stiffness or binding. Lubricate all bearing surfaces with the lubricant recommended by the manufacturer of the circuit breaker. Ascertain that all cotter pins have been opened after insertion and that all snap rings, locking plates, nuts, and so on, are in place and properly tightened. Check the stop clearance against the value given in the instruction book and adjust it if necessary. Inspect oil-filled dashpots and fill them with the same type and grade of oil as specified for the breakers with which they are used. The length of the breaker stroke and its opening and closing speeds should be measured, checked, and adjusted in accordance with directions contained in the instruction book. Make certain that the operating rod for moving the contacts does not bind against its guide. Check also for broken or distorted springs.

Operating Mechanism

Lubricate the operating mechanism in accordance with the instruction book and see that it operates freely throughout its entire stroke. Parts that are scored or show excessive wear should be repaired or replaced to conform to tolerances listed in the manufacturer's instructions. Ensure that the operating voltage at the mechanism terminals, with full operating current flowing, is adequate for correct operation. This is especially important for solenoid-operated mechanisms. Check the air pressure on pneumatically operated mechanisms to assure that it is adequate and that it is restored promptly after each breaker operation. Inspect air connections or piping for possible leaks and broken or distorted springs. In addition, make the following performance tests:

1. Check the closing relay and its contacts.
2. Check the tripping arrangement for positive tripping, including auxiliary switch adjustments and contacts. Dress or replace damaged contacts.
3. Check the pneumatically operated mechanisms and all electrically operated valves; keep the air system clean by periodic replacement of compressor filter pads, by regular blowing off of water condensation, and by systematic overhaul and cleaning of the air strainer, check valve, unloader, and other critical parts that collect dirt. Check the adjustment of all pressure switches and lockout devices. Refer to the instruction book for proper pressures.
4. Check all cotter pins, locking plates, snap rings, and nuts for tightness.

Auxiliary Equipment on Mechanism

The operating mechanism on an oil circuit breaker uses an auxiliary multiple-pole switch for making-and-breaking, closing, tripping, and position-indicating circuits. The following is the recommended inspection procedure:

1. Check all auxiliary switch contacts to see that they operate freely and make good contact. Burns sometimes occur on heavily loaded contacts, such as those for large trip coils. In such cases, remove relays if necessary to clean the contacts with fine sandpaper.
2. Check all electrical connections to the breaker mechanism and auxiliaries to see that they are tight and making good contact. Check and clean contacts and arc chutes on the auxiliary closing relay for operating the closing coil. Inspect and oil all bearings.
3. In the case of a motor-operated mechanism, inspect all electrical connections, motor bearings, and brushes, as well as all other moving parts. The speed of the closing motor is usually controlled by a variable resistor that is in series with the motor and can be adjusted for seasonal climatic changes or for adaptation to a larger or smaller circuit breaker. For further information, refer to the manufacturer's instruction manual.

Reassembly

After repair and reassembly of the circuit breaker has been accomplished, the following steps should be taken:

- Determine that the circuit is in operable condition.
- See that all tags are removed.
- Make sure that circuit protective devices are replaced and in good working condition.
- Verify that all men working on the circuit have been notified that the circuit is to be energized and that they are in the clear.
- Close all isolating or backup switches.

After the above steps have been taken, close the breaker to restore service or energize the circuits, keeping the face turned away and one hand free.

Troubleshooting

Table 6-1 shows some common troubles encountered in power circuit breakers and gives the causes and remedies of each.

OVERLOAD DEVICES

An electrical system can be damaged beyond repair by heat and flame resulting from prolonged overload. Therefore, it is expedient to use a device which can detect an overload before damage occurs, that either warns the CE of the hazardous condition or automatically turns off the power. Relays have been designed (for both d-c and a-c systems)

Table 6-1.—Troubleshooting Chart for Power Circuit Breakers

Trouble	Cause	Remedy
Overheating	Poor condition of contacts:	
	1. Out of proper alignment and adjustment.	1. Contacts should be lined up and adjusted properly.
	2. Burned and pitted because of lack of attention after many heavy operations, or too frequent operation.	2. Burned and pitted contacts (other than silver) should be dressed up, if practical, or replaced with new parts. (High-pressure butt-type contacts usually do not require dressing). Silver-to-silver contacts are very rarely dressed.
	3. Breaker kept closed (or open) for too long a period (copper contacts).	3. Operate breaker more frequently to wipe contacts clean. It may be advisable to consider the installation of new silver-to-silver contacts. The manufacturer's nearest office should be consulted.
	4. Overloading (continuous or prolonged current in excess of breaker rating).	4. If the breaker is overheating because of excess current, one of two remedies can be followed. a. replace with breaker having adequate rating for the present or future load; b. arrange circuits so as to remove the excess load.
	5. Transmission of heat to the breakers from overheated or inadequate cables or connection bars.	5. If the bars or cables overheat because of current in excess of their capacity, this can be remedied by increasing the carrying capacity (that is, increasing the size or number conductors) or by removing the excess current from the circuit.
	6. Loose connections or terminal connectors.	6. Tighten.
Failure to trip	1. Mechanism binding or sticking. Caused by lack of lubrication or mechanism out of adjustment.	1. Lubricate mechanism. Adjust all mechanical devices, such as toggles, stops, buffers, and opening springs, according to manufacturer's instruction book.

Table 6-1.—Troubleshooting Chart for Power Circuit Breakers—continued

Trouble	Cause	Remedy
Failure to trip--(continued)	2. Failure of latching device.	2. Examine surface of latch. If worn or corroded, replace. Check latch wipe, and adjust according to instruction book.
	3. Damaged trip coil.	3. Replace damaged coil.
	4. Blown fuse in control circuit (where trip coils are potential type).	4. Replace blown fuse.
	5. Faulty connections (loose or broken wire) in trip circuit.	5. Repair faulty wiring. See that all binding screws are tight.
	6. Damaged or dirty contacts on tripping device.	6. Dress or replace damaged contacts or clean dirty contacts.
Failure to close or to latch closed	1. Mechanism binding or sticking because of lack of lubrication or improper adjustment of breaker mechanism.	1. Lubricate mechanism. Adjust all mechanical devices, such as toggles, stops, buffers, and opening springs, to the manufacturer's specifications.
	2. Burnout of operating (closing) coil (of electrically operated breakers) caused by operator holding control switch closed too long.	2. Replace damaged coil and teach operator how to operate properly. A better remedy would be to change the connections to include an auxiliary switch, which automatically cuts off the closing coil as soon as the breaker closes.
	3. Closing relay sticking.	3. Check or adjust closing relay.
	4. Cutoff switch operating too soon.	4. Adjust operation of cutoff switch to delay cutoff to allow breaker to close fully.
	5. Cutoff switch operating too late, causing the breaker to bounce open.	5. Readjust to reduce power at end of stroke and eliminate bounce.
	6. Insufficient control voltage (of electrically operated breaker) caused by:	
	a. Too much drop in leads.	6a. Install larger wires; improve contact at connections.
	b. On. a-c control—poor regulation.	b. Install larger control transformer. Check rectifier, and be sure it is delivering adequate d-c voltage from adequate a-c supply.

Table 6-1.—Troubleshooting Chart for Power Circuit Breakers—continued

Trouble	Cause	Remedy
Failure to close or to latch closed--(continued)	c. On d-c control—battery not fully charged or in poor condition.	c. Give battery a sustaining charge, or repair according to instructions in battery manufacturer's manual.
	7. Blown fuse in control circuits, faulty connection or broken wire in control circuit, damaged or dirty contacts in control switch (electrically operated breaker).	7. Replace blown fuse; repair faulty connection or broken wire; dress or replace damaged contacts in control switch.
Insufficient oil (in oil-circuit-breaker tanks)	Leakage of oil. Oil throw during operation.	Locate point of leakage, and repair. Tighten joints in oil lines. Fill oil tanks to proper oil level. (Modern G-2 oil-blast breakers do not throw oil when interrupting current within their rating.)
Dirty oil (in oil-circuit-breaker tanks)	Carbonization from any operations.	Drain poor oil and filter or replace with new oil. Clean inside of tank and all internal parts of breaker.
Moisture present in oil	1. Condensation of moist atmosphere. 2. Entrance of water from rain or other source.	1. Drain and filter oil or put in new oil. 2. Repair source of water entrance.
Sludging of oil	Overheating.	Filter or put in new oil. Remove source of overheating.
Gaskets leaking	Improper installation of gaskets at a previous inspection or repair. Oil saturation.	Put in new gaskets, treated in accordance with manufacturer's specifications.
Insulation failure	Absorption of moisture and accumulation of dirt, grime, carbon, and the like on bushing and insulating parts.	Thoroughly clean all insulated parts. Bake or dry out water-soaked parts (or treat in accordance with manufacturer's specifications).

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which are capable of accomplishing these protective functions. The basic difference between a-c and d-c relays is in the armature and magnet core construction.

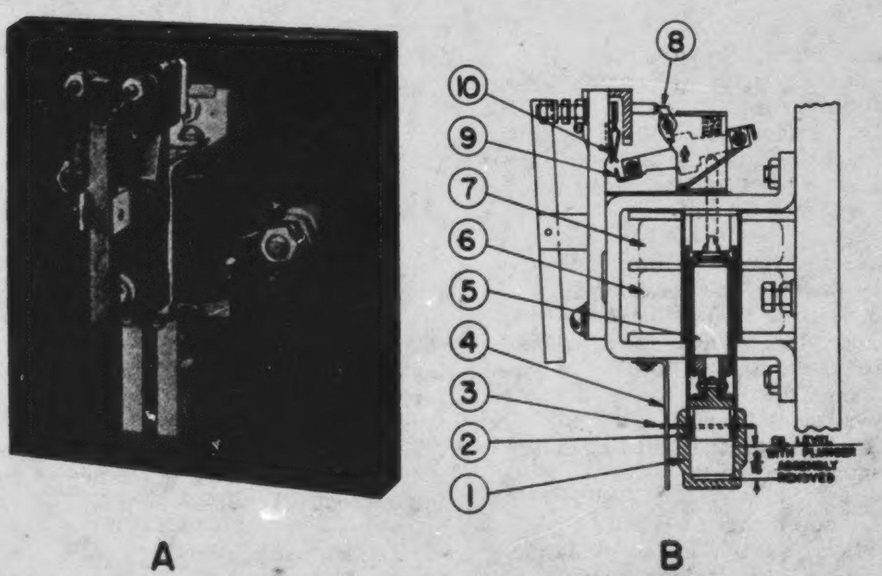
MAGNETIC TYPE

A pictorial view and a diagram identifying the various parts of magnetic type overload relay for a d-c system are shown in figure 6-9.

In an installation, the operating (series) coil ⑥ is connected in series with the protected circuit. (See ⑥ in fig. 6-9, view B.) Normal current through the coil will have no effect on relay operation. If an overload occurs, increased current will flow through the coil and cause an increase in the magnetic flux around the coil. When the flux becomes great enough, the iron plunger ⑤ will be lifted into the center of the coil, opening contacts ⑨ and ⑩ . This action opens the control circuit to the main contactor in series with the motor terminals, thereby disconnecting the motor from the line.

To keep the relay from operating when the motor is drawing a heavy but normal starting current, an oil dashpot mechanism ① and ② is built in. This gives a time delay action that is inversely proportional to the amount of overload.

Overload relays may use either single or double coils. In addition, the single-coil overload relay may be obtained with or without a manual latching control. Relays with manual latching are used on three-wire control and reset automatically after an overload has occurred. Double-coil overload relays are used for two-wire control. They have a series coil ⑥ carrying the load current and a shunt



1. DASHPOT
2. PISTON
3. INDICATING PLATE
4. CALIBRATION PLATE
5. PLUNGER
6. SERIES COIL
7. SHUNT COIL *(when used)*
8. LATCH
9. MOVABLE CONTACT
10. STATIONARY CONTACTS

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Figure 6-9.—Magnetic overload relay (d-c).

holding coil ⑦ mounted above the series coil. These two coils are connected so that their respective fields aid each other. Then, when an overload occurs the plunger moves up into the shunt-connected coil field and is held in the tripped position until the shunt coil is deenergized by the pressing of a reset button or some other form of contact (switch) device.

Before placing the overload relay in service, raise the indicating plate ③ to allow the dashpot ① to be unscrewed from the relay. Lift out the plunger ⑤ and make certain all of the internal parts are clean. Place about 9/16 of an inch of dashpot oil (furnished with the relay) in the dashpot. Replace the plunger and indicating plate, and then screw the dashpot on the relay to the desired setting.

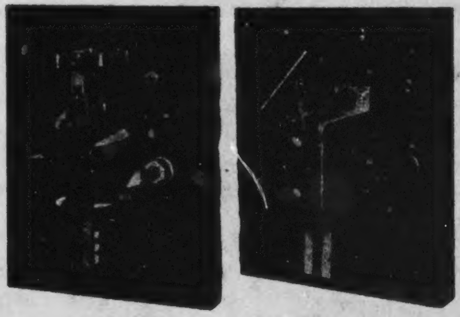
The relay is calibrated at the factory for the individual application, and the current values for which it is calibrated are stamped on the calibration plate ④. The marked values are minimum, maximum, and midpoint currents.

The operating points may be set by first raising the indicating plate ③ which allows the dashpot to be turned. Then, to lower the tripping current, raise the dashpot by turning it. This action raises the plunger further into the magnetic circuit of the relay so that a lower current will trip the relay.

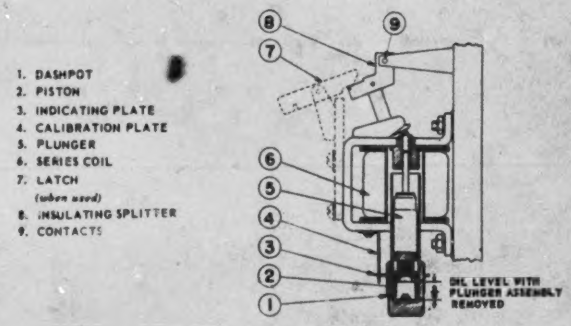
The current at which the relay trips may be increased by turning the dashpot in a reverse direction. This action reduces the magnetic pull on the plunger and requires more current to trip the relay. After the desired settings have been obtained, lower the indicating plate over the hexagonal portion of the dashpot to again indicate the tripping current and lock the dashpot in position.

Figure 6-10 shows two magnetic types of a-c overload relays. Part A is the nonlatching type, and part B is the latching type. In part C the various components are identified.

The operating (series) coil (see ⑥ in fig. 6-10, view C) is connected in series with the protected circuit. Therefore, the load current flows through the coil. If the circuit current rises above normal because of overload conditions, it will cause an increase in the magnetic lines of flux about the coil. The increased flux lifts the iron plunger ⑤ into the center of the coil and opens the contacts ⑨. This, in turn, causes the main contactor (not shown) to open, and disconnects the motor or other device from the line. An oil dashpot mechanism ① and ② is used to prevent the operation of the relay on motor starting current surges.



A-NONLATCHING B-LATCHING



C-DIAGRAM

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Figure 6-10.— Alternating-current overload relays.

If the relay does not have manual latching, a three-wire control is provided to give automatic reset after an overload occurs. The manual-latch relay is generally used with two-wire control. The latch ⑦ holds the contacts in the open position after an overload has occurred and the circuits have been deenergized. It is necessary for the operator to manually reset the overload relay at the controller.

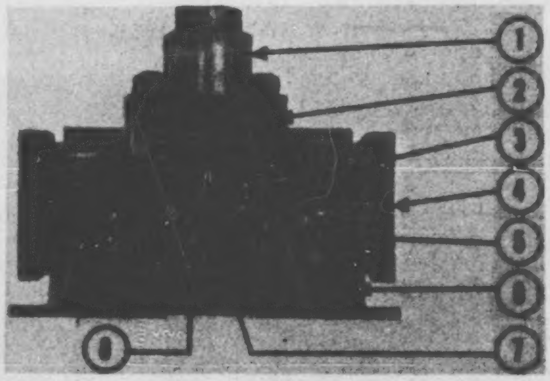
THERMAL TYPE

Thermal type overload relays (a-c and d-c) are designed to open a circuit when excessive current causes the heater coils to reach the temperature at which the ratchet mechanism releases. The heater coils are connected in series with the supply line to the load, and normal circuit current will have no effect on them.

The essential operating parts of a d-c thermal overload relay (fig. 6-11) are the two heater coils ④, two solder tube assemblies ⑤, and control contacts①. Under normal conditions the splitter arm ⑦ (so called because it splits the contacts) completes a circuit with the contacts. The spring is then under compression and the operating arm ③ tends to rotate the splitter arm out of the circuit. This action is prevented by the ratchet assembly, which is held by the solder film between the outer and inner part of the solder tubes.

When current flows through the heater coils and produces enough heat to melt the solder film, the inner part of the solder tube assembly rotates and releases the ratchet mechanism to open the control circuits. When this happens, the circuit to the coil handling the power contacts (not shown in the figure) opens and disconnects the load. As soon as the load is disconnected, the heaters cool, and the solder film hardens. When the hardening is complete, the relay is ready to be reset.

An adjustable type thermal relay with magnetic reset is illustrated in figure 6-12. This relay may be adjusted to trip at a value between 90 and 110 percent of the rated coil current. To change the operating point, loosen the binding screws that hold the relay heater coil ④ (fig. 6-11) so that the coil position may be changed. Moving the coil away from the relay will increase the amount of current needed to trip the relay. Moving the coil closer to the relay will decrease the current needed to trip the relay. This range of adjustment is available only within the range of 90 to 110 percent of coil rating. Each rating has a different manufacturer's part number. The correct rating is installed when the controller is installed. Do not use another rating. Make sure both heater coils in each overload relay are the same rating.



1. CONTACT STRUCTURE
2. SCREW
3. OPERATING ARM
4. HEATER COIL
5. SOLDER TUBE
6. SCREW
7. SPLITTER ARM

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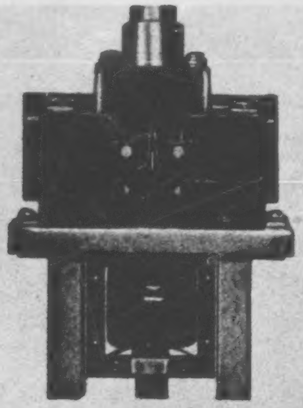
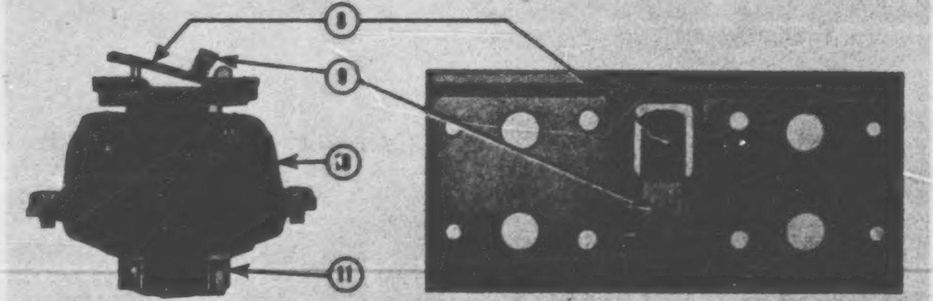
Figure 6-11.—Thermal overload relay.

The terminal plates and the underside of the slotted brackets of the heater coil assembly are serrated so that the coil is securely held in position when the binding screws are tightened. Some thermal overload relays have reset magnet assemblies attached. It may become necessary to replace the heater coils from the relay. Then remove the four screws that hold the overload relay to the mounting plate. When removing the relay from the mounting plate, use care not to lose the phenolic pin and bearing block located between the thermal blocks on the underside of the relay.

Next, remove the four large countersunk screws that hold the mounting plate and the reset magnet assembly to the square posts. Remove the four screws in the mounting plate, which support the reset magnet. Take care not to lose the lever and spring, items ⑧and⑨. Remove the two screws ⑪ and pull out the plunger guides. Remove the old coil ⑩ and install the new coil. Then insert the plunger guides and replace the screws ⑪ . Reassemble the magnet, spring, and lever to the mounting plate. Mount the plate on the posts and then mount the overload relay on the mounting plate. Replace the heater coils as the last operation.



RESET MAGNET ASSEMBLY



DETAILS OF RESET MAGNET

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Figure 6-12.—Adjustable thermal relay with magnetic reset.

Overload relays are PROTECTIVE DEVICES. After an overload relay has performed its safeguarding function it must be reset by the CE before the system can again be run with overload protection.

REVERSE CURRENT AND PHASE-FAILURE DEVICES

An electrical distribution system can be overheated and damaged when two or more generators are employed, provided a condition exists which reverses the CURRENT in a d-c system, or reverses the POWER in an a-c system. Obviously, devices are needed t provide protection against these hazards.

To plug a motor is to stop the motor by setting the controls for reversing its direction of rotation. This practice is used wit electric propulsion. Because propulsion typ a-c motors require full voltage and curren from all three phases supplied by the generator, phase-failure protection is a requirement where this type of propulsion is used

REVERSE-CURRENT RELAY

Two or more d-c generators may be connected in parallel to supply sufficient powe to a circuit. Each d-c generator is driven by its own prime mover. If one prime mover fails, its generator will slow down and draw power from the line. The generator will then operate as a motor and instead of furnishing power to the line, it will draw power from the line. This can result in damage to the prime mover and overloading of the generator. To guard against this possibility, reverse-current relays are used. The reverse-current relay connections are such that when the reverse power reaches a definite percentage of the rated power output, it will trip the generator circuit breaker, disconnecting the generator from the line.

Normally, the reverse-power settings for d-c relays are about 10 percent of rated generator capacity for d-c generators. The reverse-current relay (one for each generator) is located on the generator switchboard. The mechanical construction of a d-c relay designed to limit reverse-current flow is illustrated in figure 6-13. Note that the construction is similar to that of a bipolar motor with stationary pole pieces and a rotation armature.

The potential coil is wound on the armature, and a current coil is wound on the stationary pole pieces. When used as a protective device, the current coil is in series

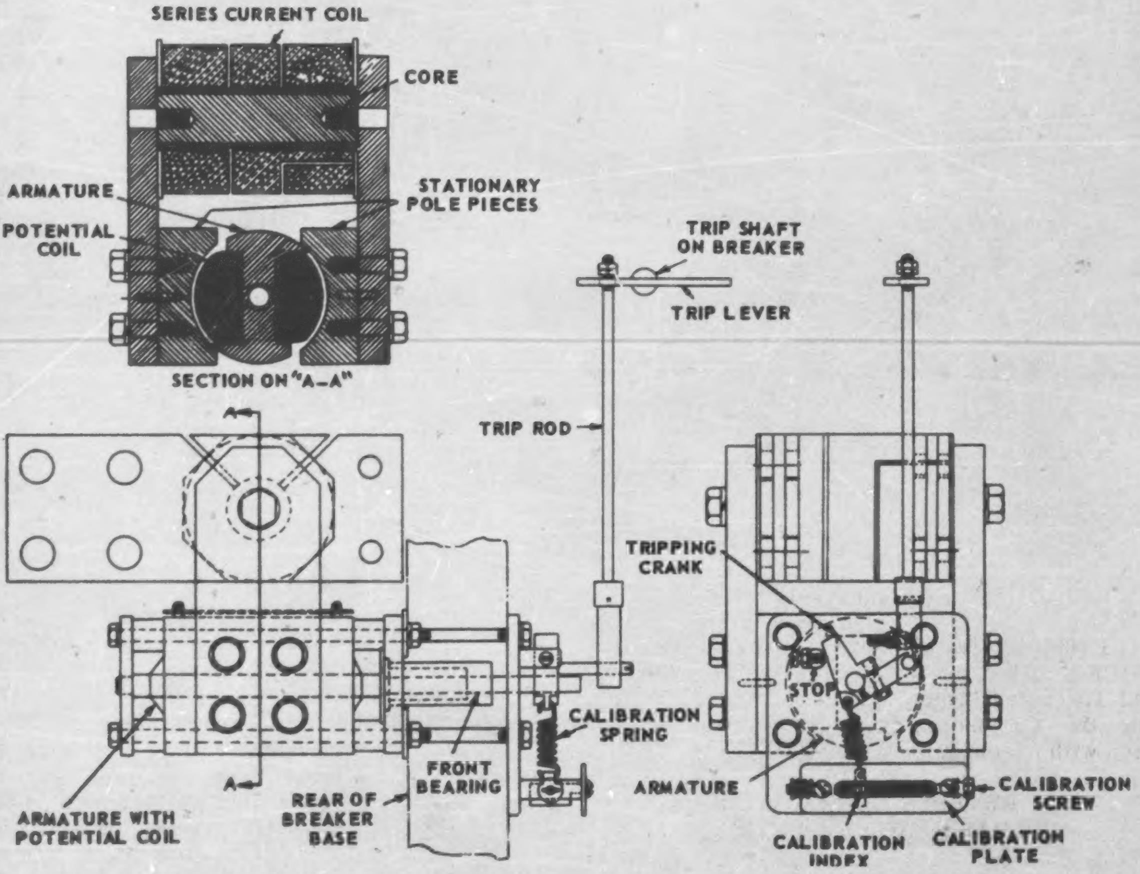
SERIES CURRENT COIL
CORE
ARMATURE
STATIONARY POLE PIECES
POTENTIAL COIL
SECTION ON "A–A"
TRIP SHAFT ON BREAKER
TRIP LEVER
TRIP ROD
A
TRIPPING CRANK
STOP
CALIBRATION SPRING
FRONT BEARING
REAR OF BREAKER BASE
A
ARMATURE WITH POTENTIAL COIL
ARMATURE
CALIBRATION SCREW
CALIBRATION INDEX
CALIBRATION PLATE

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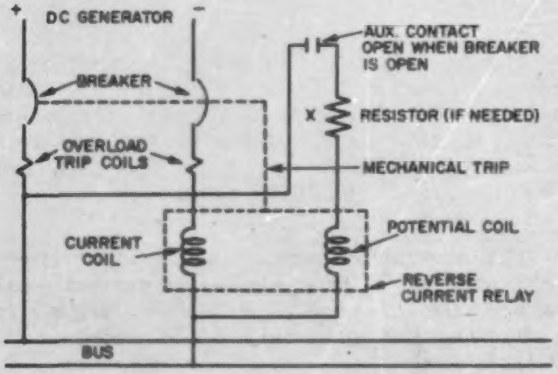
Figure 6-13.—Mechanical construction of d-c reverse-current relay.

with the load, and the potential coil is connected across the line, as shown in figure 6-14. If the line voltage exceeds the value for which the potential coil is designed, a dropping resistor is connected at point X in the circuit.

When the line is energized, current flowing through the series coil produces a magnetic field across the air gap. Voltage applied to the armature winding produces a current in the armature coil, which interacts with the magnetic field, thereby developing a torque that tends to rotate the armature in a given direction. The construction of the relay is such that the armature cannot turn through 360 degrees as in a motor. Instead, the torque produced by the two fields, plus the force from the calibrated spring, tends to hold the tripping crank on the armature shaft against a fixed stop. This pressure is maintained as long as current flows through the line in the right direction.

However, if one generator fails, the voltage output of that generator will drop. When the voltage drops below the terminal voltage of the bus to which it is connected, the generator terminal current (through the relay series coil) will reverse. However, the polarity of the voltage applied to the potential coil remains the same. As soon as the reversed current exceeds the calibration setting of the relays, the armature rotates, and through a mechanical linkage, trips the circuit breaker that opens the bus. This action disconnects the generator from the line.



77.104

Figure 6-14.—Direct-current reverse-current relay connections.

REVERSE-POWER RELAY

Reverse-power protection is required when two or more a-c generators are connected to the same line. Unless such protection is provided, failure of a prime mover can result in the generator running as a motor. An a-c reverse-power relay differs in construction from d-c reverse-current relays. The a-c type consists of two induction disk type elements. The upper element is the timer, and the lower one is the direction element.

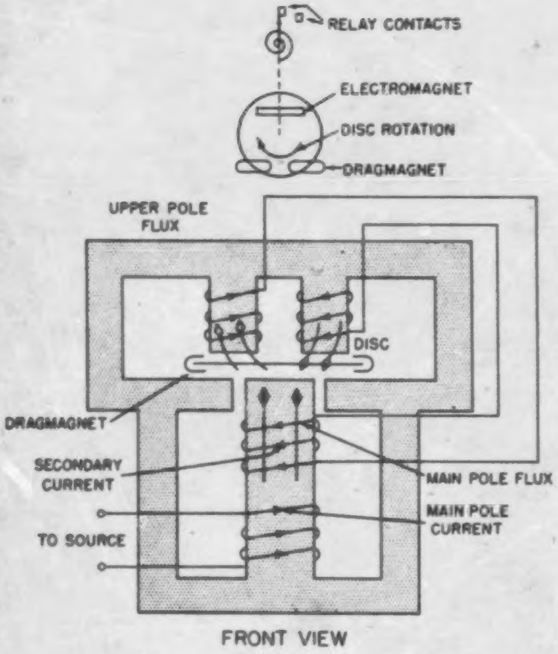
Figure 6-15 shows the coil and induction disk arrangement in the induction type relay timer element. The disk is four inches in diameter and is mounted on a vertical shaft. The shaft is mounted on bearings for minimum friction.

An arm is clamped to an insulated shaft, which is geared to the disk shaft. The moving contact, a small silver hemisphere, is fastened on the end of the arm. The electrical connection to the contact is made through the arm and a spiral spring. One end of the spring is fastened to the arm and the other end to a slotted spring adjuster disk fastened to a molded block mounted on the element frame. The stationary contact is attached to the free end of a leaf spring. The spring is fastened to the molded block, and a setscrew makes it possible to adjust the stationary contact position.

The main relay contacts (not shown in the figure) will safely handle 30 amperes at 250 volts d-c and will carry the current long enough to trip a breaker.

The induction disk is rotated by an electromagnet in the rear of the assembly. Movement of the disk is dampened by a permanent magnet in front of the assembly.

The operating torque of the timer element is obtained from the electromagnets (fig. 6-16). The main-pole coil is energized by the line voltage. This coil then acts as the primary of a transformer and induces a voltage in the secondary coil. Current then flows through the upper pole coils and thus produces a torque


RELAY CONTACTS
ELECTROMAGNET
DISC ROTATION
DRAGMAGNET
UPPER POLE FLUX
DISC
DRAGMAGNET
SECONDARY CURRENT
MAIN POLE FLUX
MAIN POLE CURRENT
TO SOURCE
FRONT VIEW

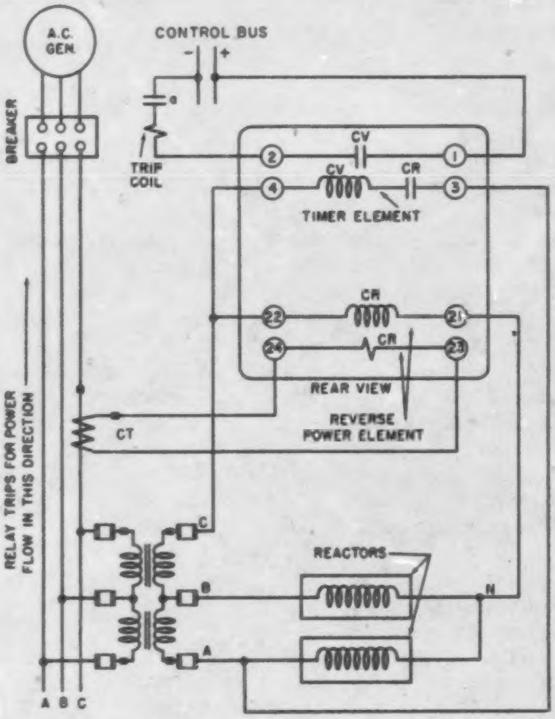
77.105

Figure 6-15.—Coil and disk arrangement, a-c reverse-power relay.

on the disk because of the reaction between the fluxes of the upper and lower poles.

The timer element cannot be energized unless the power flow is in the direction that will cause tripping. This interlocking action is accomplished by connecting the timer potential coil in series with the contacts of the directional element. Thus, the direction of power flow controls the timer relay.

The directional element is similar to the timing element, except that different quantities are used to produce rotation of the disk. There is also a different contact assembly. The two upper poles of the electromagnet are energized by a current that is proportional to the line current, and the lower pole is energized by a polarizing voltage. The fluxes produced by these two quantities cause rotation of the disk in a direction depending upon the phase angle between the current and voltage. If the line power reverses, the current through the relay current coils will reverse with respect to the polarizing voltage and provide a directional torque.


A.C. GEN.
CONTROL BUS
-
+
BREAKER
a
TRIP COIL
CV
2
1
CV
CR
4
3
TIMER ELEMENT
CR
22
21
CR
24
23
REAR VIEW
REVERSE POWER ELEMENT
CT
RELAY TRIPS FOR POWER FLOW IN THIS DIRECTION
C
B
A
REACTORS
N
A B C

77.106

Figure 6-16.—Schematic of an a-c reverse-power relay.

The contact assembly and permanent magnet construction are the same as that used for the timer element. The timer element is rated at 115 volts, 60 hertz. The minimum timer element trip voltage is 65 volts, and its continuous rating is 127 volts.

The directional element has a power characteristic such that, when the current and voltage are in phase, maximum torque is developed. The potential coil is rated at 70 volts, 60 hertz.

The current coil rating is 5 amperes, and the minimum pickup current is 0.1 ampere through the coil. This current is in phase with 65 volts (minimum) across the potential coil. These are minimum trip values, and the timing characteristic of the timing relay may be erratic with low values.

For maximum protection and correct operation, the relay should be connected so that maximum torque occurs for unity power factor on the system. Because the directional element has power characteristics, this connection may be accomplished by using line to neutral voltage for the directional element potential coil (polarizing voltage) and the corresponding line current in the series coils. If a neutral is not available, a dummy neutral may be obtained by connecting two reactors, as shown in figure 6-16. When connected in this manner, the directional element voltage coil forms one leg of a Y connection, and the reactors form the other two legs of the Y. The voltage-operated timer element should be connected across the outside legs of the transformer secondaries.

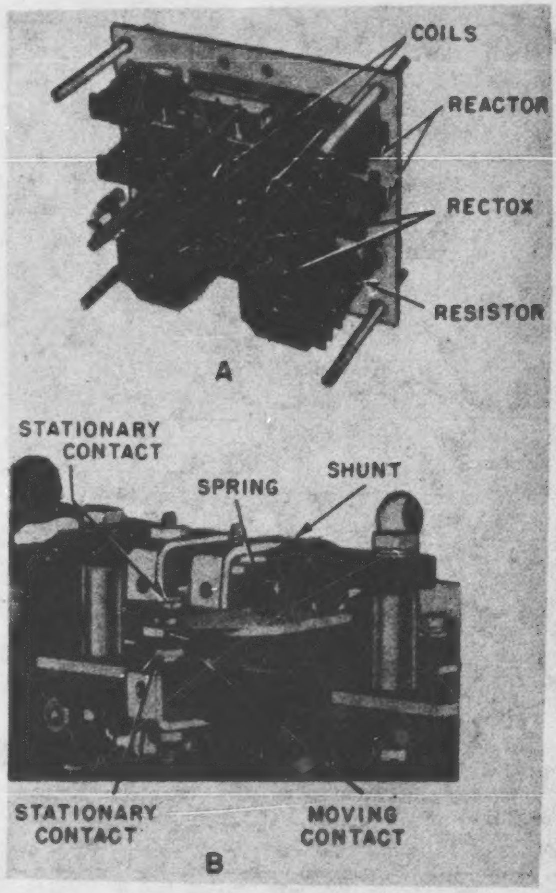
PHASE-FAILURE RELAY

This type of relay is used to detect short circuits on alternating current propulsion systems. Ordinary instantaneous trip relays cannot be used. As an example, when the motor's direction of rotation is reversed on full voltage, the momentary current may be as great as the short circuit current.

The relay in use operates when there is a current unbalance. It is connected in the control circuit so that it will shut down the system instantly in case of an external or internal fault. However, operation of the relay is not limited to short-circuit detection, and the relay may be used as a phase-failure relay. A phase-failure relay is shown in figure 6-17. Part A is the arrangement of the parts in the complete assembly, and part B is a closeup of the contact assembly. The entire unit is enclosed in a cover to prevent dirt and dust from interfering with its operation.

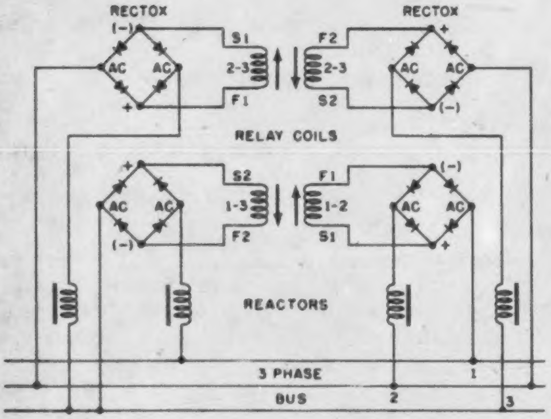
The moving contact is the only moving element in the complete relay. There are two stationary contacts that make it possible to have the relay open or close a circuit when it operates.

Two coils are built into the relay. Each coil has two windings that are actuated by direct current from the two Rectox units. Four reactors are used to get sensitivity over a wide frequency range. Because variations in reactance are introduced during manufacture, two resistors are provided to balance the systems during the initial adjustment.



77.107
Figure 6-17.— Phase-failure relay.

Figure 6-18 is the schematic wiring diagram for the phase-failure relay. The coils are represented by circles with numbers inside the circles that refer to numbered leads in the 3-phase bus. The coil (1-3) is connected to lines 1 and 3; the coil (1-2) is connected to lines 1 and 2; and the two coils



77.108
Figure 6-18.—Schematic wiring of a phase-failure relay.

(2-3) are connected to lines 2 and 3. However, the coils are not directly connected to the bus lines. Instead, connection is made through the Rectox units, which are connected to the line in series with a reactor.

When all three phase voltages are balanced, the flux produced by coil (1-2) is exactly equal and opposite to that produced by coil (2-3). The flux produced by coil (1-3) is exactly equal and opposite to that produced by the other (2-3) coil. Therefore, the resultant flux is zero, and no magnetic pull is exerted on the armature of the relay.

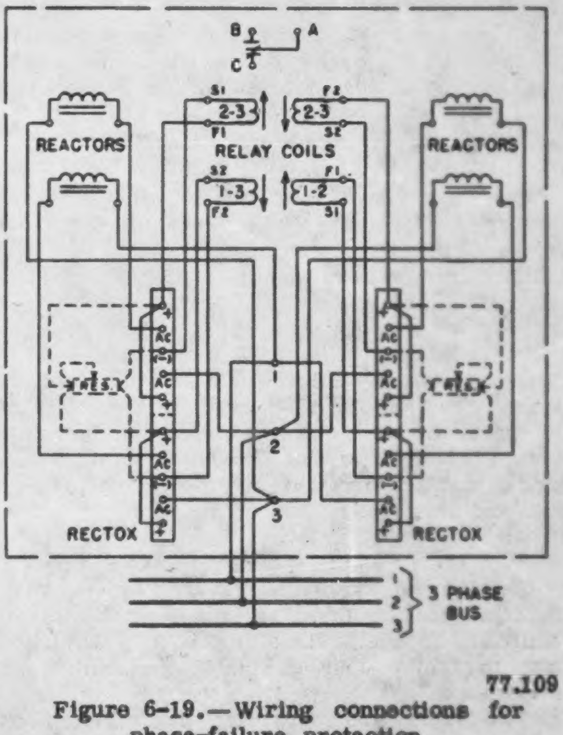
If a short circuit is placed across lines 1 and 2, no flux is produced by coil (1-2). This means that the flux produced by one of the (2-3) coils is no longer balanced, and there is a resultant flux, which exerts pull on the relay armature. The armature moves until the moving contact hits stationary contact 2 (fig. 6-17, view B). This action opens the circuit between the moving contact and stationary contact 1. As soon as the short circuit is removed from lines 1 and 2, the resultant flux is zero, which allows the spring to return the armature to its original position. Similarly, if shorts occur on lines 2 and 3 or lines 1 and 3, the resultant flux is no longer zero, and the relay will operate.

A heavy copper tube is placed on each magnet core to damp out the triple-frequency ripple caused by the 120-degree displacement of the 3-phase voltages.

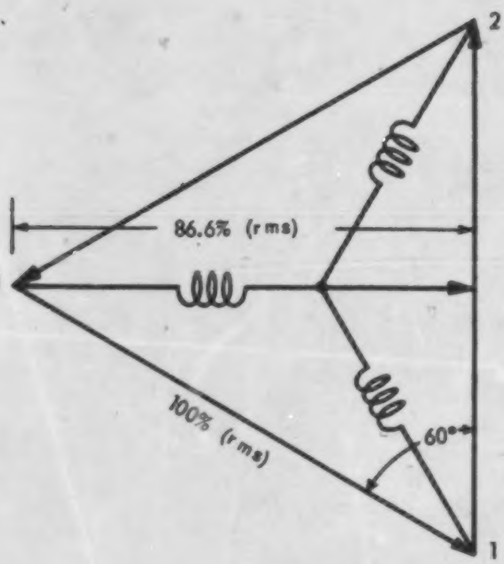
Figure 6-19 illustrates a wiring diagram of the relay, and figure 6-20 presents a vector diagram showing what happens to the line voltage when two lines are short-circuited. Suppose a short occurs across lines 1 and 2. The voltage on coil 1-2 will then be zero and the average voltage on coils 1-3 and 2-3 will be 100% sin 60°/1.11 = 78 percent of the normal rms value with no short. This voltage unbalance is enough to trip the relay.

The reactor in series with each coil keeps the coil current essentially constant over a frequency range of 12 to 90 hertz so that the relay sensitivity is as great at 12 as at 90 hertz.

Mention was made of the use of resistors to achieve magnetic balance. If the reactor



77.109
Figure 6-19.—Wiring connections for phase-failure protection.



77.110
Figure 6-20.—Vector diagram showing perfect short-circuit on 3-phase system.

reactances are essentially equal, the resistors are not needed. However, if manufacturing tolerances are such as to introduce unbalance, the resistors are necessary. To determine if the resistors are needed, connect a 3-phase, 115-volt, 60 hertz voltage to terminals 1, 2, and 3, as shown in figure 6-19. Short coils 1-3 and 2-3 (on a common core), and then remove the armature spring for that relay. Put the armature against the core. No pull should be exerted on it. If there is pull, a resistance is needed. Repeat this test for coils 2-3 and 1-3 with the coils 2-3 and 1-2 shorted.

Never open the d-c circuit to the Rectox rectifier while the voltage is being applied to the a-c side. This precaution is necessary because the voltage across the Rectox is only a small portion of the total voltage drop due to the reactor being in the circuit. If the d-c side is opened, full voltage is applied across the Rectox, which may cause it to break down.

Very little maintenance is required for this relay. No lubrication is needed. However, the relay should be kept clean so that dirt and dust will not interfere with its operation.

Because the relay rarely operates, it is advisable to check its operation every one or two months. To do this short circuit the coil connections one at a time. Do this with a tool that has an insulated handle to avoid electric shock. When the coil is shorted, the armature will drop because the coil is no longer energized. When the short is removed, the armature will return to its normal position.

GROUNDING

Proper grounding performs as a very effective and potent protective device. Safety is accomplished by two types of grounds: system ground and equipment ground. It is important that you learn the distinction between the two.

A SYSTEM GROUND is a connection from one of the current-carrying conductors of distribution system to ground.

An EQUIPMENT GROUND is considered to be a connection to ground from one or more noncurrent-carrying metal parts of a wiring system or of apparatus to the system. Motor frames, switch boxes, outlet boxes and metal boxes of controllers are examples of equipment grounds.

A system ground prevents a rise in voltage beyond that for which the system was designed. This rise can be caused by lightning, inadvertent contact with high voltage lines, or a defective component. Grounding electrodes, rods, and connectors, properly connected, reduce the hazard of these higher voltages to personnel and equipment.

Equipment grounds are made to minimize the danger when a person contacts the metal frame of any equipment that is alive due to insulation failure or improper wiring. Elimination or reduction of fire hazards is accomplished simultaneously since any live circuit can cause a fire.

SPECIFICATIONS AND CODES

Whenever you make installations or repairs, you must abide by the rules of the Naval Facilities Engineering Command type specifications, which require that grounds be installed in accordance with the National Electric Code (NEC) and the National Electrical Safety Code. An exception to these codes is that grounds and grounding systems are required to have a resistance to solid earth ground which does not exceed the following values in ohms:

Generating stations 1

Main substations, distribution substations, switching stations on a primary distribution system, metal enclosures of electrical and electrically operated equipment, cable sheaths of connecting cables and systems to which portable electrical utilization equipment or appliances are connected 3

Secondary distribution systems (neutral), noncurrent-carrying metal parts associated with distribution systems, and enclosures of electrical equipment not normally within reach of other than authorized and qualified electrical operating and maintenance personnel, individual transformer and lightning arrester grounds on a distribution system, and equipment not covered above 10

Section 250 of the NEC describes the minimum requirements for establishment of common grounding systems, the location of grounding connections, methods for grounding, bonding techniques, types of grounding electrodes, the sizes of various grounding conductors, and so on. It is essential that you become familiar with this section. Why?

Your life and the lives of other men depend upon strict adherence to the minimum regulations specified therein. Remember, too, that the National Fire Protection Association which sponsors the NEC states that the code regulations are minimal.

CONTROLLERS

A controller regulates the operation of electrical equipment. A controller for electric motors is simply a starter which provides a convenient and safe means of performing several or all of the following functions:

1. Start and stop
2. Accelerate and decelerate
3. Regulate the speed
4. Reverse

In some applications the motor must be frequently started, stopped, and reversed, in addition to having its speed varied continually. Some a-c motor controllers stop motors quickly by plugging. Plugging is the interchanging (by relays) of any two leads of a 3-phase motor to reverse the direction of rotation of the a-c field with respect to that of the rotor.

Motors up to 1 horsepower (hp) can usually be started or stopped by closing or opening a switch that connects the motor directly to the power source. To provide automatic protection against overload, fuses or circuit breakers may be incorporated in the design of the main switch. Motors rated from 1/20 to 1 hp, are sometimes furnished with the socalled sentinel breaker. The sentinel breaker is a small combination switch and circuit breaker containing a bimetallic thermal element. This thermal element will not trip immediately when an overload occurs; however, if there is a sustained heavy load the breaker will trip before the motor is damaged.

TYPES

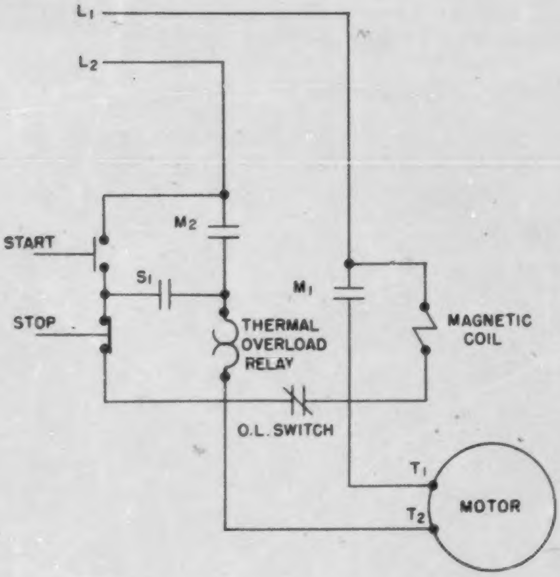
Some of the most common types of controllers used with a-c motors are:

1. Across-the-line starters
2. Primary resistor starters
3. Secondary resistor starters
4. Autotransformer or compensator starters
5. Star delta starters

Regardless of the type of controller, all of them have overload protective devices, and most of them give low-voltage protection or low-voltage release protection. Many controllers are designed to withstand high mechanical shock and are equipped with manual latches or automatic latching relays to prevent false operation. Some typical controllers and wiring diagrams are shown in this chapter. A thorough knowledge of controller circuits and their operating characteristics will help you to install, maintain, and repair a-c controllers.

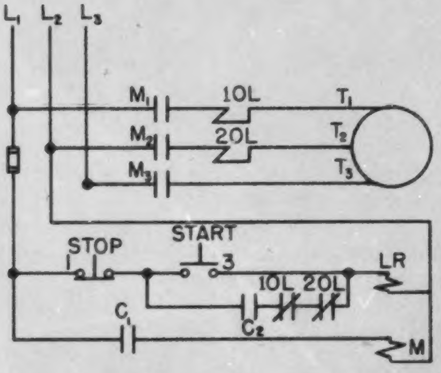
Magnetic Across-The-Line Starters

A single-phase pushbutton magnetic across-the-line starter connection is illustrated in figure 6-21. Both line leads are connected to the motor terminals through the main contacts K_1 and K_2, which close or open when the appropriate button is pushed. The thermal relay protecting the motor is connected in series



26.14

Figure 6-21.—Line diagram of a single-phase magnetic across-the-line controller.



26.15

Figure 6-22.—Schematic of a three-phase magnetic across-the-line starter with three-wire remote control.

with L_2 in figure 6-21. A control circuit supplying the magnetic coil is connected across the main line. (The light line in fig. 6-21 is the control circuit; the heavy line is the main circuit.)

The magnetic coil circuit can be opened either by pressing the STOP button or by operation of the thermal overload relay. Both of these actions deenergize the magnetic coil and open contacts K_1, K_2 and K_3.

When the START button is depressed, the control circuit is connected across the line. The magnetic coil is energized and closes the main contacts K_1 and K_2, which connect the motor across the line. The holding contact K_3 is also closed by the magnetic coil and remains closed after release of the START button to keep the magnetic coil energized.

Illustrated in figure 6-22 is a line diagram of a 3-phase magnetic across-the-line starter. The 3-phase magnetic across-the-line controller operates on the same principle as the single-phase unit except there are three line leads connected to the motor. Notice in figure 6-22 that the motor protecting thermal overload relay heaters are in series with L_1 and L_2 to the motor. Normally, only two thermal overload relays are required to adequately protect the 3-phase motor. Three are required when the motor is isolated, inaccessible or at unattended locations.

When the START button is depressed, a circuit is completed from L_1 through the START and STOP buttons and the coil of latching relay (LR) to L_2. The coil of LR is energized and LR operates to close relay contacts LR_1 and LR_2. This action completes a circuit through coil A. Coil A is energized and closes the main line contacts A_1, A_2, and A_3; this action connects the motor directly across the line.

The latching relay contact LR_1 completes the circuit to the coil (A) of the main line contactor. Contacts LR_1 and LR_2 are mechanically connected by a lever which prevents them from opening as a result of a shock. Also, when the latching relay opens, it operates a mechanical latch which prevents the main contactor from closing while it is electrically deenergized.

When the STOP button is depressed, the latching relay is deenergized and contacts LR_1 and LR_2 open. This deenergizes the magnetic coil of the main contactor and causes the main contacts to open.

You will notice that the overload relay contacts are in the control circuit, but are operated by heating elements (not shown) placed in the main lines. The control circuit is FUSED to protect it when remote control switches are used. Many starters also give LOW-VOLTAGE PROTECTION by allowing the magnetic contactor to open when the line voltage fails or goes below a certain value. When the voltage is restored to its normal value, the motor will not start again until the START button is depressed.

Primary Resistor Controllers

Primary resistor starters are used on motors to reduce the sudden surge of current on starting, or when it is desirable to avoid sudden mechanical shock to the driven load. A representative line diagram of a magnetic primary resistor starter is illustrated in figure 6-23. Notice that the resistors are connected in the motor circuit.

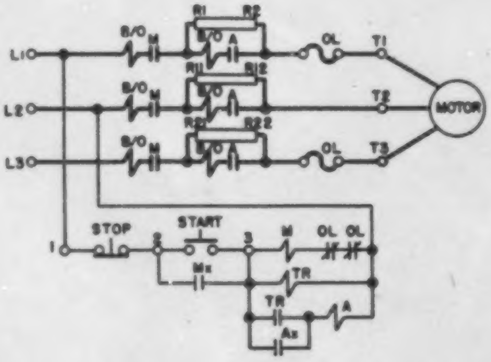
The two-point magnetic type starter is suitable for most applications. The two-point type starter is generally made up of an accelerator control, an overload relay, a timing relay, starting resistors, and a line contactor.

In operation the line contactor coil (A) is energized first and starting contacts A_1, A_2, A_3 close, energizing the motor through the starting resistors. Then the time relay (TR) is activated after a predetermined time interval, energizing the accelerating contactor coil (B), whose contacts B_1, B_2, and B_3 close, and short out the starting resistances, thereby placing the motor directly across the line. The motor now runs at full speed because all resistance has been cut out.

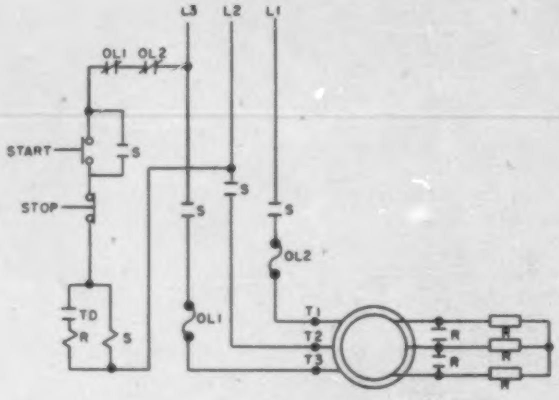
Secondary Resistor Controllers

The magnetic secondary resistor controller is used in conjunction with a wound rotor motor requiring automatic acceleration. This type of starter (fig. 6-24) usually consists of primary contactors, starting duty resistors for the motor secondary, overload relays, and the required number of timed-accelerating contactors.

In operation, depressing the starter button closes the main line contactors, placing the rotor in series with the resistors and the stator directly across the line. The contacts of the timed accelerator progressively short out the secondary resistance until the slip rings are short circuited, thereby bringing the motor up to full speed.



26.16
Figure 6-23.—Schematic of a two-point resistor starter.



26.17
Figure 6-24.—Line diagram of a secondary resistor starter.

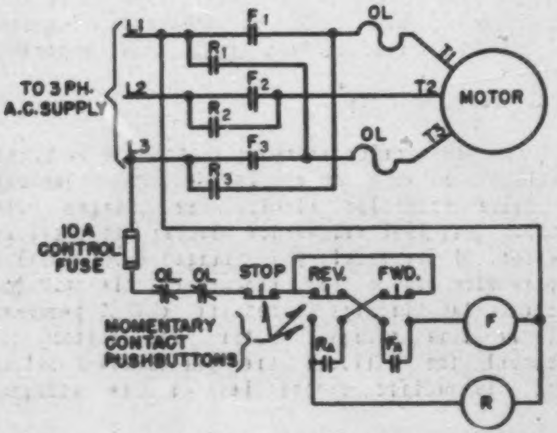
REVERSING CONTROLLERS

Certain equipment, such as elevators, lathes, and hoists, requires a driving motor that can be reversed. The reversal of an a-c (3-phase) induction motor is accomplished by interchanging any two of the three leads to the motor. The connections for an a-c reversing-type controller are illustrated in figure 6-25. The STOP, REVERSE, and FORWARD pushbutton controls are all of the momentary-contact type. Note the connections to the REVERSE and FORWARD switch contacts. The circles with F and R inside represent magnetic contactor coils.

If the FORWARD pushbutton is pressed, coil F will be energized and will close its holding contacts, FA. These contacts will remain closed as long as coil F is energized. When the coil is energized it closes line contacts F1, F2, and F3. This applies full-line voltage to the motor. The motor then runs in a forward direction until the voltage supply is interrupted.

If either the STOP button or the REVERSE button is pressed, the circuit to the F magnetic contactor coil will be broken and the contactor coil will release and open line contacts F1, F2, F3, and holding contact FA.

If the REVERSE pushbutton is pressed, coil R will be energized and will close holding contacts RA and line contacts R1, R2, and R3. Note that R contacts reverse the connections of lines 1 and 3 to motor terminals T1 and T3. This causes the motor rotor to rotate in the reverse direction. The F and R contactors are mechanically interlocked to prevent both being closed at the same time.



77.146

Figure 6-25.—An a-c reversing controller.

Momentary contact pushbuttons provide low-voltage protection with manual restart in the circuit shown in figure 6-25. If either the F or R magnetic coil is deenergized, the contactor will not reclose and start the motor when voltage is restored unless the FORWARD or REVERSE pushbutton is pressed. The circuit arrangement of the pushbuttons constitutes an electrical interlock that prevents energizing both coils at the same time.

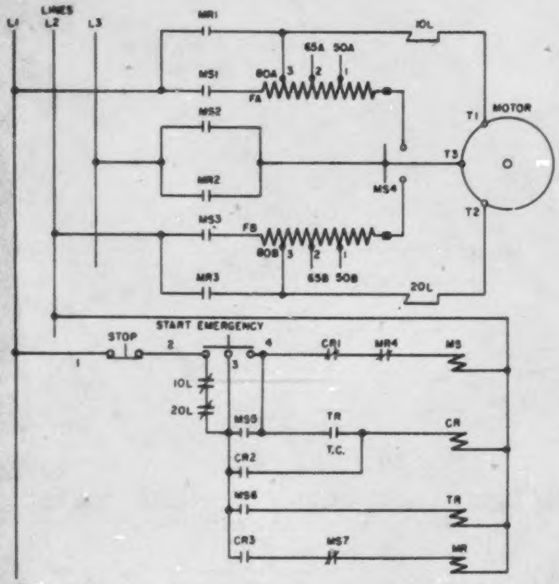
Reduced Voltage Controllers

An autotransformer starter reduces the voltage applied to the motor during the initial starting period. It is used advantageously where high starting line currents must be reduced (more than with resistor starters), or where the starting torque of the motor must be adjusted to meet the particular load requirement.

One advantage of the autotransformer is that the action of the transformer, rather than the resistance, reduces the voltage; therefore, no energy is lost through heat. A disadvantage of this type starter is a temporary, but complete, loss of power on the motor terminal when the motor is disconnected from the transformer taps and transferred to the powerline.

The autotransformer is a dual unit with separate windings on the outside legs. The windings are connected in open delta to supply reduced voltage to a 3-phase motor during the starting period. Each winding is tapped to provide starting voltages at the motor of 50 percent, 65 percent, or 80 percent of the line voltage. It is possible to change the connections to the transformer taps to get higher or lower starting voltage. It is necessary to select the tap for the desired starting voltage when making the original connections.

A complete schematic diagram of a motor starter using autotransformers as well as other control devices is given in figure 6-26. Because a number of separate controls are shown in schematic form, the action will be traced from the time the START button is pressed.



77.145
Figure 6-26.—Schematic of motor starter using autotransformers and other control devices.

This control is a spring-loaded button, which completes the circuit between two contacts.

The START button, when pressed, completes the circuit from L1 and the button contacts through the normally closed contacts CR1 and MR4, and through the starting coil MS to L2. When the starting coil, MS, is energized, it attracts an armature, which operates seven contacts. Four of these contacts (MS1, MS2, MS3, and MS4) connect the autotransformer in open delta across the line.

The fifth contact, MS5, completes the holding circuit to the starting coil. The holding circuit is from L1 through the STOP button, to normally closed contacts OL_1 and OL_2 through contact MS5, to normally closed contacts CR1 and MR4, and then through coil MS to L2.

The sixth contact, MS6, completes the circuit to the timer relay, TR. This circuit path is from L1 through the STOP button, through the normally closed contacts OL_1 and OL_2, through contact MS6, and through the timer relay coil TR to L2.

The seventh contact, MS7, is normally closed, and when relay MS operates, it opens the circuit to the coil of motor running contactor, MR, so that MS7 acts as an electrical interlock. Thus, contact MS7 prevents magnetic contactor coil MR from being energized when MS is operated. This action prevents a portion of the autotransformer winding from being short-circuited by contacts MR1 and MS1 or MR3 and MS3. After a time interval for which the timing relay is set, the mercury timer, TR, closes the circuit to the control relay, CR, governing the running contactor, MR.

The control relay contacts, CR1, open the holding coil circuit to the main starting coil, MS, permitting the starting contactor to open. Contacts CR2 close and energize the holding circuit for relay coil CR. Contacts CR3 close in preparation for energizing the running contactor coil, MR.

During the transition from reduced voltage to full voltage, relay MS opens and temporarily disconnects the transformer and motor from the circuit. During this time the motor is free-running with no connection to the line. However, this interval is of short duration because the opening of MS completes the circuit to the main running coil, MR, through the seventh or interlock contact, MS7, the MR coil then closes contacts MR1, MR2, and MR3 to connect the motor directly across the line. Electrical interlock MR4 opens to prevent the starting coil, MS, from being energized at the same time that MR is energized.

Full line voltage is applied to the autotransformer primary. Starting current supplied at reduced voltage is higher than line current during this period. The usual time limit for bringing a loaded motor to two-thirds or more of its full speed is between 20 to 30 seconds.

Star Delta Starting

The star delta starting method of reduced voltage can only be applied to motors having a delta connected winding that changes the motor terminal connection during the starting period. If the winding is changed from a delta connection to a star connection, the voltage across the windings is reduced to 57.7 percent of the line voltage. After the motor is started, the windings are reconnected delta, and the voltage across them is line voltage.

All the phase leads are brought out to the terminal box, so that the connection may be easily changed.

Figure 6-27 is a wiring diagram of a magnetic controller used for star delta starting. When the start button is depressed, magnetic contactor coil K is energized and closes contacts K_1, K_2, and K_3, which connect phase leads T_2, T_4, and T_6 across the line. At the same time, relay R and magnetic contactor coil S are energized. Contactor S closes S_1, S_2, and S_3, which connect phase leads T_1, T_3, and T_5 together. The motor winding is then star connected and connected across the line.

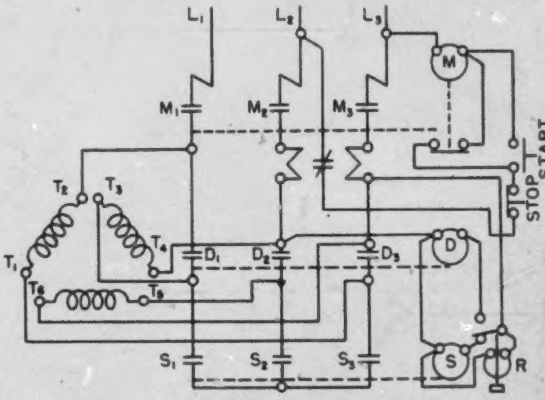
Relay R is a time delay relay. After a predetermined time delay, it opens the control circuit of contactor S and closes the control circuit of contactor D. Contactor S opens contacts S_1, S_2, and S_3. Contactor D closes contacts D_1, D_2, and D_3. Contacts D_1, D_2, and D_3 connect T_1, T_3, and T_5 to T_6, T_2, and T_4, respectively, and make a delta connection of the stator winding. Contacts K_1, K_2, and K_3 remain closed so that the motor is connected across the line.

SAFETY CODE FOR MOTORS AND MOTOR PROTECTION

Thermal cutouts and relays, and other devices for motor-running protection which are not capable of opening short circuits, must be protected by fuses or circuit breakers. The rating or setting of these protective devices must not exceed the limitations prescribed in the National Electric Code. Refer especially to Articles 430-31 through 145 in the 1975 edition of this code.

A motor-running protective device which can restart a motor automatically after over-current tripping must not be installed unless approved for use with the motor which it protects. A motor which can restart automatically after shutdown must be installed so that its automatic restarting cannot result in injury to personnel.

Motor-running overcurrent devices other than fuses must have a trip rating not less than 115 percent nor more than 125 percent of the full load current rating of the motor, unless permitted otherwise by the National Electric Code.



26.20

Figure 6-27.—Wiring diagram for a star delta magnetic controller.

MOTOR INSTALLATION IDENTIFICATION

In installing motors or motor controllers, various requirements are necessary for the safety of personnel and equipment. Below are some of the requirements for motor markings.

A motor should be provided with a nameplate showing the maker's name, the rating in volts and amperes, including those of the secondary. The nameplate should state the normal full-load speed of the motor, if it is a wound-rotor type. This identification must also include the interval during which the motor can operate at full-load starting cold, before reaching its rated temperature. The time interval should be 5, 15, 30, or 60 minutes, or continuous.

A motor rated at 1/8 horsepower or larger should have the horsepower rating marked on the nameplate except that the motors of arc welders may be marked in amperes.

An alternating current motor rated at 1/2 horsepower or larger, unless it is a polyphase wound-rotor motor, should have the nameplate marked with a code letter to show its input in kilovolt-amperes with locked rotor.

SOME REQUIREMENTS FOR MOTOR CONTROLS AND MOUNTINGS

Controllers must show the manufacturer's name or symbol; the voltage rating or ratings;

the horsepower capacity or current-carrying capacity; any data needed to indicate for what type of motor the controller is suitable; and terminal numbering (for example, L_1, L_2, T_1, and so on).

Control cabinets may not be used as a junction box, raceway, and so on, for circuits containing apparatus other than the motor and controller connections.

Motors must be located so that:

1. Adequate ventilation is provided.

2. Maintenance such as lubrication of bearings and replacing of brushes can be readily accomplished.

3. Sparks from the commutator or collector rings will not cause fire hazards.

4. They are within sight of and not more than 50 feet from the controlling means, unless the controller disconnecting means is capable of being locked in the open position, or a manually operable switch which will disconnect the motor from its source of supply is placed within sight of the motor location.

The frames of stationary motors must be grounded. All motors, whether stationary or otherwise, must also be permanently and effectively grounded.

The preceding are but a few of the requirements for the installation of motors and their controls. If there is any doubt in your mind about the requirements for the installation of motors and their controls, you should consult the appropriate Navy specification or National Electrical Code.

MAINTENANCE OF CONTROLLERS

The most important rule to remember when making repairs or inspecting motor controllers is: BE SURE THE CONTROLLER IS DISCONNECTED FROM THE POWER SOURCE BEFORE TOUCHING ANY OF THE OPERATING PARTS.

After the power source is disconnected, you can go ahead with your work. The first thing that should be done to keep controllers operating at maximum efficiency is to keep them free from dirt, dust, grease, and oil, both inside and out. Clean the operating mechanism and contacts with a clean, dry, lint-free cloth, or with a vacuum cleaner. Small and delicate mechanical parts may be cleaned with a small, stiff bristle brush and a Navy approved solvent. NEVER USE CARBON TETRACHLORIDE.

If the manufacturer's instruction sheets for a device indicate bearing surfaces are to be lubricated, the bearing surfaces should receive a few drops of light oil, and all excess oil should be wiped off. In general, bearings which operate on a shaft or pin require lubrication, but knife edge bearings and plunger type armatures, which may become gummed up, SHOULD NOT BE OILED.

Copper Contacts

Copper contacts are used for most heavy duty power circuits, and in many cases, in relay and interlock circuits. They should be inspected regularly. If projections extend beyond the contact surfaces, or if the contacts are pitted or coated with copper oxide, they should be dressed down with fine sandpaper.

Welding of contacts sometimes occurs. In spite of all precautions, low voltage is the most common cause. Welding may also result from overloads, low contact pressure resulting from wear or weak springs, loose connections, or excessive vibrations. If welding occurs, it is an indication of trouble in the electrical system. The contacts will have to be replaced, but it is useless to replace them unless the cause of the welding is found and corrected.

Carbon Contacts

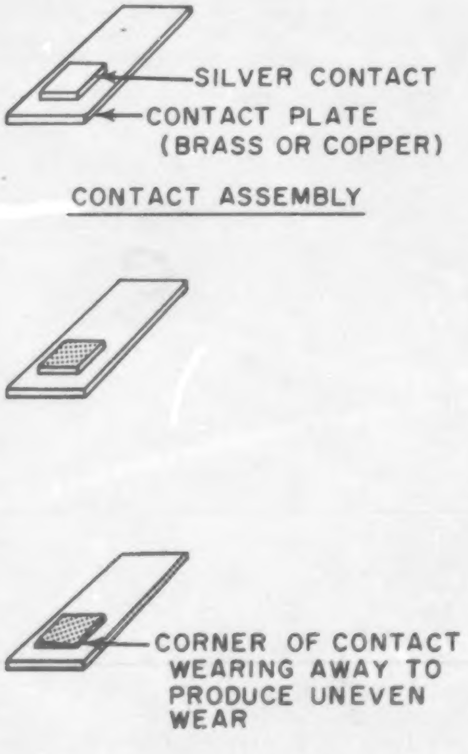
Carbon contacts are used when a contactor is frequently opened and closed. It is essential that the contactor be open when it is deenergized. Since carbon contacts will not weld together when closed, they are better than metal contacts for ensuring that a deenergized contact is open. Carbon contacts are used only when necessary; however, because the current capacity of carbon per square inch of contact surface is very low, the contacts made of carbon must be relatively large.

Silver Contacts

Silver contacts are used extensively in pilot and control circuits, on relays, interlocks, master switches, and so on. They are used also on smaller controllers, and on heavy duty equipment where the contactors remain closed for long periods of time with infrequent operation. Silver contacts are used because they ensure better contact than other less expensive material.

Pure silver contacts and silver cadmium-oxide contacts should not be replaced until they become too worn to give good service. Their appearance will indicate when they are worn to such an extent that they are no longer serviceable. (See fig. 6-28.)

Normally, contacts are subjected to electrical and mechanical wear as they establish and interrupt electric currents. Electrical wear is usually greater than mechanical wear. If a movable contact assembly has no appreciable sliding action on its associated stationary contact assemblies, mechanical wear will be insignificant.



26.21

Figure 6-28.—Silver contact.

Electrical wear or erosion is caused by arcing when the contacts are establishing and interrupting currents. During arcing, a small part of each contact is melted, vaporized, and blown away from the contact.

As a pure silver contact erodes, its arcing surface changes in color, contour, and smoothness. Figure 6-28 shows typical changes in contour and smoothness.

Normally, a new contact has a uniform silver color, a regular contour, and a smooth arcing surface. As the contact wears, discolorations usually give it a mottled appearance, showing silver, blue, brown, and black. The black color comes from the silver oxide formed during arcing. Silver oxide is beneficial to the operation of the contact.

Electrical erosion may cause uneven wear of the contacts and consequent contour irregularity. Uneven contact wear does not necessarily indicate that the contact should be replaced. To allow for uneven contact wear, manufacturers usually provide a total thickness of silver equal to twice the wear allowance associated with the contact.

Melting and vaporization of contacts cause pitting of the arcing surface. The pitted surface has high spots which are quite small in area; tests indicate that such a surface is better than a surface which has not been subjected to arcing, because its circuit-making reliability is improved.

A silver-cadmium-oxide contact shows the same wear characteristics as a pure silver contact, except that small black granules may be evident on the arcing surface. These granules are cadmium oxide, a black material which is scattered throughout the mixture that has formed on the contacts. Silver oxide is formed during arcing, just as with a pure silver contact. The addition of cadmium oxide greatly improves contact operation because it minimizes the tendency of the contacts to weld together, retards heavy transfer of material from one contact to the other, and inhibits erosion.

A contact is serviceable as long as its wear-allowance and that of its associated contacts exceed minimum value specified by the manufacturer. (Usually the minimum value is in the order of 0.015 to 0.030 inch.) The wear-allowance of contacts is defined as the total thickness of contact material which may be worn away before the contact of two associated surfaces becomes inadequate to carry rated current.

In an electric-motor contactor, the wear-allowance of the powerpole contacts is usually related to the closed position of the magnetic operator. The wear-allowance of the powerpole contacts of a magnetic contactor is the amount of silver that can be worn away without resulting in a failure of contacts to touch when the magnetic operator is at its closed position.

Blowout Coils

Blowout coils seldom wear out or give trouble when used within their rating. However, if they are required to carry excessive currents, the insulation becomes charred and fails, causing flashovers and failure of the device.

Arc shields are constantly subjected to the intense heat of arcing and may eventually burn away, allowing the arc to short circuit to the metal blowout pole pieces. Therefore, arc shields should be inspected regularly and renewed before they burn through.

Arc barriers provide insulation between electrical circuits and must be replaced if broken or burned to a degree where short circuits are likely to occur.

The importance of having clean, tight electrical connections must be emphasized. Where practical, it is a good idea and a common practice to solder electrical connections.

Excessive slam on closing, particularly on a-c magnetic-operated devices, will eventually damage the laminated face of the magnet armature and may damage the shading coil.

Magnetic coils should be kept dry. Wet coils should always be dried out before using. They may be dried by baking them in a well-vented oven at not more than 194° F to prevent water from boiling in the insulation. The length of time in the oven depends on the size of the coil. If an oven is not available, place the unit under a canvas cover roomy enough for hot air to be circulated within. Another alternative would be to direct infrared ray lamps on the windings.

Troubleshooting

Table 6-2 is a troubleshooting chart for a-c controllers.

CONTROL DEVICES

For our purposes here, a CONTROL DEVICE—in its simplest form—is an electrical switching device that applies voltage to, or removes voltage from, a single load. In more complex control systems, the initial SWITCH may set into action other CONTROL DEVICES that govern the motor speeds, the room temperature, the depth of water, the aiming and firing of guns, or the direction of guided missiles. In fact, all electrical systems and equipment are controlled in some manner by one or more CONTROLS.

Control devices are introduced in Basic Electricity, NAVPERS 10086-B. In this chapter we will cover the construction and maintenance of a variety of these control devices.

MANUALLY OPERATED SWITCHES

Manually operated switches are those familiar electrical items which can be conveniently operated with the hand. The pushbutton (fig. 6-29) is the simplest form of electrical control. When the button is pushed down (fig. 6-29, view A), contact is made across the two circles representing wire connections. When pressure is released, a spring opens the contact. Figure 6-29, view B shows a normally closed contact. When it is pressed, contact at the two terminals is broken. When

Table 6-2.—Troubleshooting Chart for Alternating-Current Controllers

Trouble	Probable cause	Remedy
Failure to close	No power.	Check power source. Replace faulty fuses.
	Low voltage.	Check power-supply voltage. Apply correct voltage. Check for low power factor.
	Inadequate lead wires.	Install lead wires of proper size.
	Loose connections.	Tighten all connections.
	Open connections and broken wiring.	Locate opens and repair or replace wiring. Remove dirt from controller contacts.
	Contacts affected by long idleness or high operating temperature.	Clean and adjust.
	Contacts affected by chemical fumes or salty atmosphere.	Replace with oil-immersed contacts.
	Inadequate contact pressure.	Replace contacts and adjust spring tension.
	Open circuit breaker.	Check circuit wiring for possible fault.
	Defective coil.	Replace with new coil.
	Overload-relay contact latched open.	Operate hand- or electric-reset.
Failure to open	Interlock does not open circuit.	Check control-circuit wiring for possible fault. Test and repair.
	Holding circuit grounded.	Test and repair or replace grounded parts.
	Misalignment of parts; contacts apparently held together by residual magnetism.	Realign and test for free movement by hand. Magnetic sticking rarely occurs unless caused by excessive mechanical friction or misalignment of moving parts. Wipe off pole faces to remove accumulation of oil.
	Contacts welded together.	See CONTACTS WELDED TOGETHER section.
Sluggish Operation	Spring tension too strong.	Adjust for proper spring tension.
	Low voltage.	Check power-supply voltage. Apply correct voltage.
	Operating in wrong position.	Remount in correct operating position.
	Excessive friction.	Realign and test for free movement by hand. Clean pivots.
	Rusty parts due to long periods of idleness.	Clean or renew rusty parts.

Table 6-2.—Troubleshooting Chart for Alternating-Current Controllers—continued

Trouble	Probable cause	Remedy
Sluggish Operation (Continued)	Sticky moving parts.	Wipe off all accumulations of oil and dirt. Bearings do not need lubrication.
	Misalignment of parts.	Check for proper alignment. Realign to reduce friction and test for free movement by hand.
Erratic Operation (Unwanted Openings and Closures and Failure of Overload Protection)	Short circuits.	Test and repair or replace defective parts.
	Grounds.	Test and repair or replace defective parts.
	Sneak currents.	These are usually caused by intermittent grounds or short circuits in the machines or wiring circuit. Test and replace faulty parts or wiring.
	Loose connections.	Tighten all connections. Eliminate any vibrations or rapid temperature changes that may occur in close proximity to the controller.
Overheating of Coils	Shorted coil.	Replace coil.
	High ambient temperature or poor ventilation.	Relocate controller, use forced ventilation or replace with suitable type controller.
	High voltage.	Check for shorted control resistor. Check power-supply voltage. Apply correct voltage.
	High current.	Check current rating of controller. Make check for high voltage above. If necessary, replace with suitable type controller.
	Loose connections.	Tighten all connections. Check for undue vibrations in vicinity.
	Excessive collection of dirt and grime.	Clean but do not reoil parts. If covers do not fit tightly, realign and adjust fasteners.
	High humidity, extremely dirty atmosphere, excessive condensation, and rapid temperature changes.	Use oil-immersed controller or dusttight enclosures.
	Operating on wrong frequency.	Replace with coil or proper frequency rating.

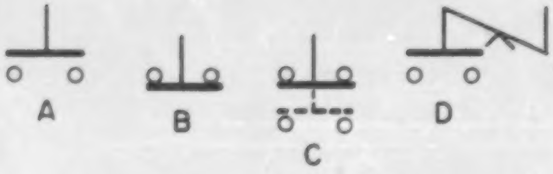
Table 6-2.—Troubleshooting Chart for Alternating-Current Controllers—continued

Trouble	Probable cause	Remedy
Overheating of Coils (Continued)	D-c instead of a-c coil.	Replace with a-c coil.
	Too frequent operation.	Adjust to apply larger control.
	Open armature gap.	Adjust spring tension. Eliminate excessive friction or remove any blocking in gap.
Contacts Welded Together	Improper application.	Check load conditions and replace with a more suitable type controller.
	Excessive temperature.	Smooth off contact surface to remove concentrated hot spots.
	Excessive binding of contact tip upon closing.	Adjust spring pressure.
	Contacts close without enough spring pressure.	Replace worn contacts. Adjust or replace weak springs. Check armature overtravel.
	Sluggish operation.	See SLUGGISH OPERATION.
	Rapid, momentary, touching of contacts without enough pressure.	Smooth contacts. Adjust weak springs. Where controller has JOG or INCH control button, operate this less rapidly.
Overheating of Contacts	Inadequate spring pressure.	Replace worn contacts. Adjust or replace weak springs.
	Contacts overloaded.	Check load data with controller rating. Replace with correct size contactor.
	Dirty Contacts.	Clean and smooth contacts.
	High humidity, extremely dirty atmosphere, excessive condensation, and rapid temperature changes.	See OVERHEATING OF COILS.
	High ambient temperature or poor ventilation.	See OVERHEATING OF COILS.
	Chronic arcing.	Adjust or replace arc chutes. If arcing persists, replace with a more suitable controller.
	Rough contact surfaces.	Clean and smooth contacts. Check alignment.
	Continuous vibration when contacts are closed.	Change or improve mounting of controller.
	Oxidation of contacts.	Keep clean, reduce excessive temperature, or use oil-immersed contacts.

Table 6-2.—Troubleshooting Chart for Alternating-Current Controllers—continued

Trouble	Probable cause	Remedy
Arcing At Contacts	Arc not confined to proper path.	Adjust or renew arc chutes. If arcing persists, replace with more suitable controller.
	Inadequate spring pressure.	Replace worn contacts. Adjust or replace weak springs.
	Slow in opening.	Remove excessive friction. Adjust spring tension. Renew weak springs. See SLUGGISH OPERATION.
	Faulty blowout coil or connection.	Check and replace coil. Tighten connection.
	Excessive inductance in load circuit.	Adjust load or replace with more suitable controller.
Pitting or Corroding of Contacts	Too little surface contact.	Clean contacts and adjust springs.
	Service too severe.	Check load conditions and replace with more suitable controller.
	Corrosive atmosphere.	Use airtight enclosure. In extreme cases, use oil-immersed contacts.
	Continuous vibration when contacts are closed.	Change or improve mounting of controller.
	Oxidation of contacts.	Keep clean, reduce excessive temperature, or use oil-immersed contacts.
Noisy Operation (Hum or Chatter)	Poor fit at pole face.	Realign and adjust pole faces.
	Broken or defective shading coil.	Replace coil.
	Loose coil.	Check coil. If correct size, shim coil until tight.
	Worn parts.	Replace with new parts.
Vibration after Repairs	Misalignment of parts.	Realign parts and test for free movement by hand.
	Loose mounting.	Tighten mounting bolts.
	Incorrect coil.	Replace with proper coil.
	Too much play in moving parts.	Shim parts for proper tightness, and clearance.

26.160.4

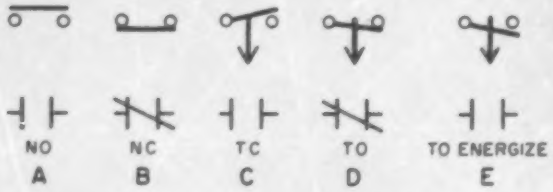


73.291
Figure 6-29.—Manually operated contacts.

it is released, a spring-loaded feature closes the switch again. The switch in figure 6-29, view C is designed to make one contact and break another when it is pressed: the upper contact is opened when the lower is closed; again, the spring arrangement reset the switch to the position shown. The switch in figure 6-29, view D is a maintained contact type. When it is pressed, it hinges about the center point and will stay in that position until the other part of the button is pressed.

ELECTRICALLY OPERATED SWITCHES

Control switches, illustrated in figure 6-30, identify several symbols used to indicate the positions of contacts. View A of the illustration is shown in the normally open (NO) position; therefore the contact closes when operated. View B is shown in the normally closed (NC) position; therefore, when energized, the contact opens. Views C, D, and E are timer contacts; that is, after being energized, some time is required for these contacts to close or open as the case may be. This timed element may be controlled pneumatically, by a timer motor, a dashpot, or by magnetic flux. Notice that devices that are timed to close or open have this indicated on the schematic: TC means timed to close; TO means timed to open; and TO ENERGIZE means that while this contact is already shown open, before it can be timed to open it must close. This switch is closed by a clutch in the timer assembly and, after a timer motor operates through a given number of revolutions, will then have the clutch in the timer release the contact and reopen the switch. The timed switches may also be illustrated with an arrow which indicates whether the contact is timed to open or timed to close, as the arrow direction indicates.



73.292
Figure 6-30.—Electrically operated contacts.

RELAYS

Contacts for relays perform the same functions as switches. When triggered electrically, note some of the possible operations and their designations in figure 6-31. A possible contact spring arrangement is shown in figure 6-32 for a class E relay.

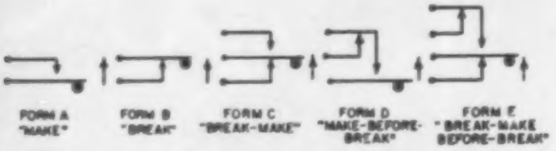
When the coil of a relay (fig. 6-33) is energized or deenergized, the contacts make and/or break as designed, if the relay is working properly, to complete or break connections to a variety of circuitry attached to coil terminals.

How is this accomplished? The armature of the relay is attracted to the energized coil. As it pivots on its hinge pin, an armature arm applies pressure to the various contacts, thus making or breaking circuit connections as shown in figure 6-31 or 6-32.

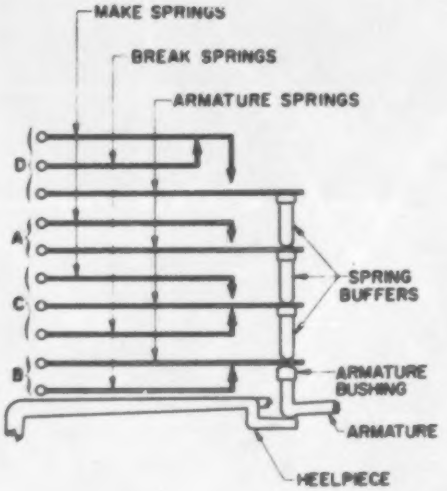
Relays have a variety of possible protective enclosures and terminals. Be sure you specify the type used originally when you replace a defective relay (fig. 6-34).

PHOTOELECTRIC CONTROL RELAYS

Photocell relays may be used to control street-lighting circuits by turning on the lights when natural illumination falls below a predetermined level. Two types are in use: those generating their own energy in the light collector (fig. 6-35) and those using a phototube


FORM A
"MAKE"
FORM B
"BREAK"
FORM C
"BREAK-MAKE"
FORM D
"MAKE-BEFORE-BREAK"
FORM E
"BREAK-MAKE BEFORE-BREAK"

73.293X
Figure 6-31.—Contact combinations.


MAKE SPRINGS
BREAK SPRINGS
ARMATURE SPRINGS
D
A
C
B
SPRING BUFFERS
ARMATURE BUSHING
ARMATURE
HEELPIECE

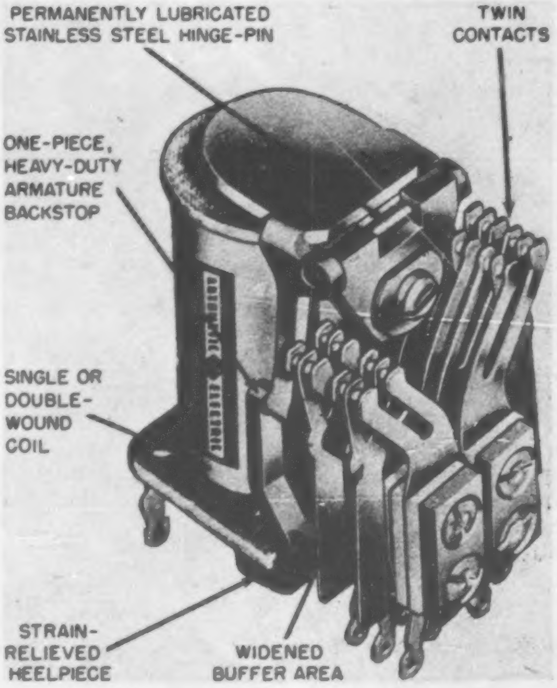
73.294X
Figure 6-32.—Contact spring arrangement.

and additional vacuum tubes to operate the relay.

To avoid interference from vehicular or other artificial lights, the light collector (electric eye) should be mounted on the pole supporting the street-circuit control apparatus or on a nearby building. It should face north and upward; the phototube photoelectric relay should be mounted in a similar position (fig. 6-36).

Since dust or dirt on the windows of photoelectric cells or phototubes prevents proper operation, these windows must be kept clean. Photocell windows should be cleaned if the lights come on too early in the evening.

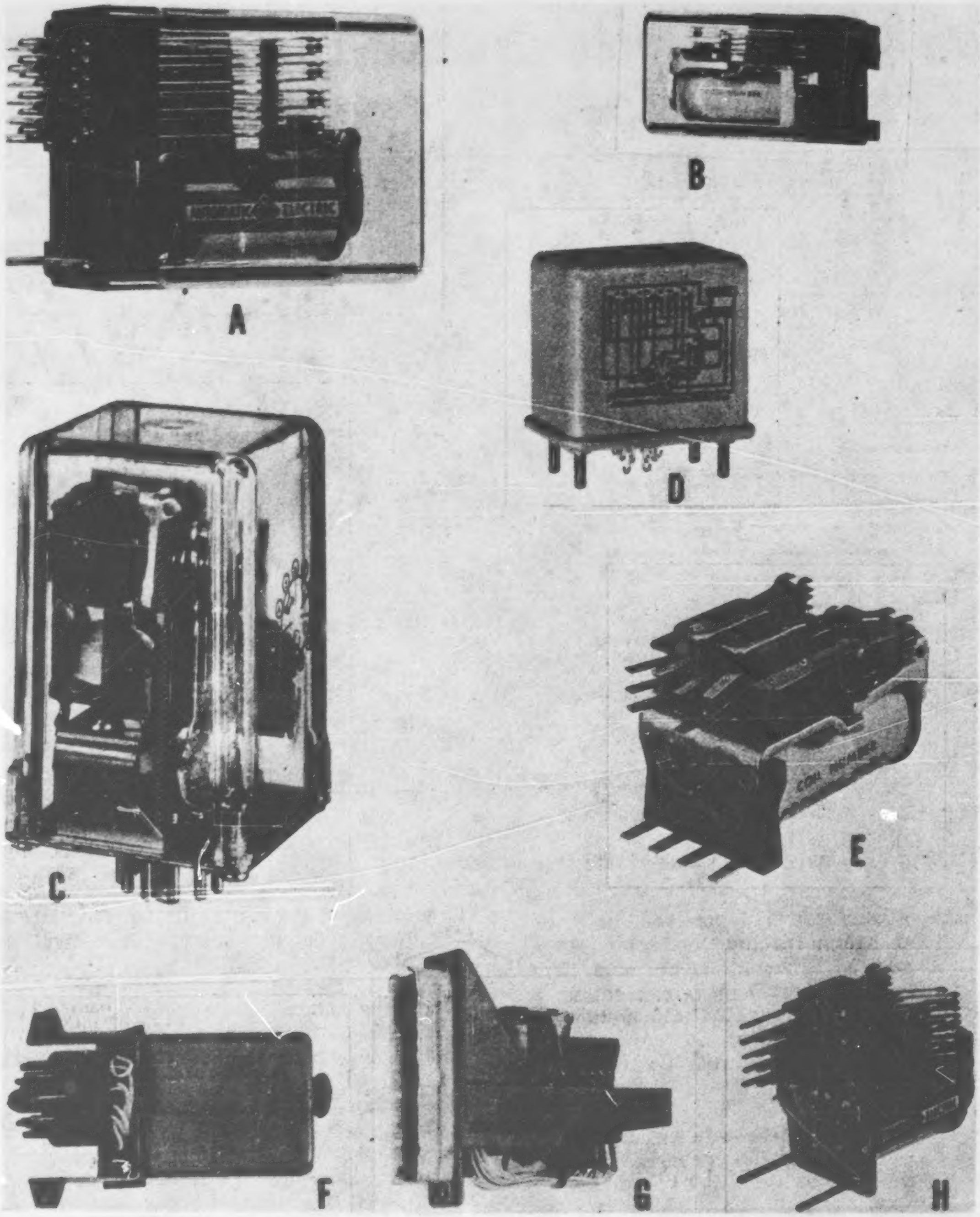
SELF-GENERATING TYPE.—The self-generating photronic cell (fig. 6-37) has a normal clear day output of 1 1/2 to 6 milliamperes. However, it will operate the relay on 1/2 milliampere, so replacing the light collector is not necessary until its output tests below 1/2 milliampere. This test should be made on a cloudless day with a milliammeter with a range of 0-10 milliamperes. The check can be made most conveniently at the terminals on the relay box (fig. 6-37).


PERMANENTLY LUBRICATED STAINLESS STEEL HINGE-PIN
TWIN CONTACTS
ONE-PIECE, HEAVY-DUTY ARMATURE BACKSTOP
SINGLE OR DOUBLE-WOUND COIL
STRAIN-RELIEVED HEELPIECE
WIDENED BUFFER AREA

73.295X
Figure 6-33.—Representative relay.

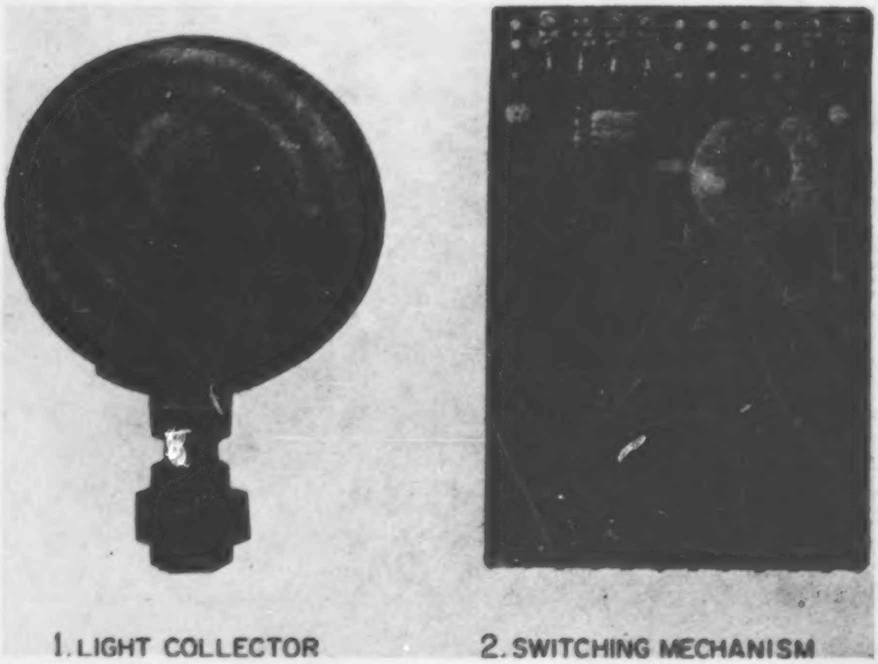
When the output of the light collector tests less than 1/2 milliampere, it should be returned to the manufacturer for rehabilitation.

The relay for this photocell is very delicate because of the small amount of energy available to operate it. The two most common trouble sources are sticking contacts and damaged bearings. Sticking contacts should be carefully cleaned with fine sandpaper. Damaged bearings are usually caused by severe continuous vibration. For this reason, the box should be installed where it is free from



73.296X

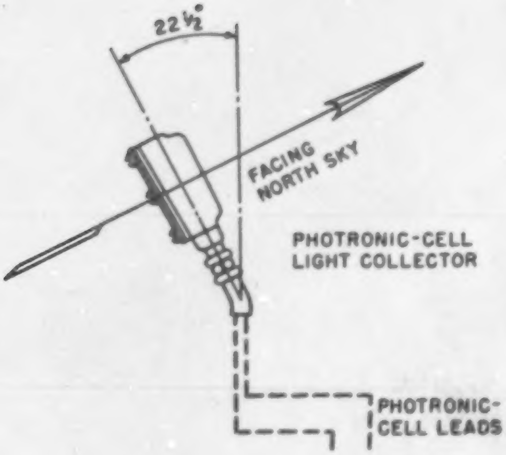
Figure 6-34.—Relay terminals and enclosures.



1. LIGHT COLLECTOR 2. SWITCHING MECHANISM

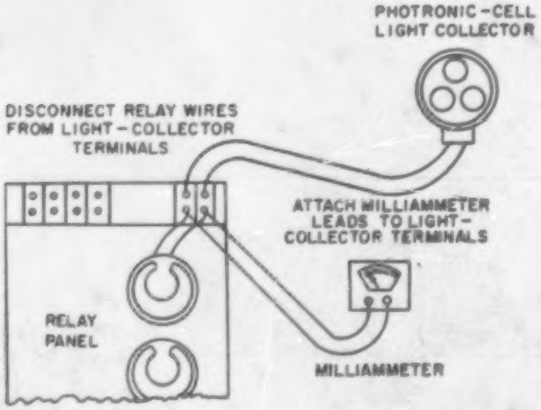
26.183(73G)

Figure 6-35.—Principal parts of a photoelectric relay.


22½°
FACING NORTH SKY
PHOTRONIC-CELL LIGHT COLLECTOR
PHOTRONIC-CELL LEADS

73.297X

Figure 6-36.—Phototube photoelectric relay properly mounted.


PHOTRONIC-CELL LIGHT COLLECTOR
DISCONNECT RELAY WIRES FROM LIGHT-COLLECTOR TERMINALS
ATTACH MILLIAMMETER LEADS TO LIGHT-COLLECTOR TERMINALS
RELAY PANEL
MILLIAMMETER

26.184

Figure 6-37.—Method of checking output of photoelectric cell.

severe vibration or knocks. Any maintenance on the relay panel other than the cleaning of contacts mentioned above should be done by the manufacturer. Careful handling is essential.

PHOTOTUBE TYPE.—For the phototube photoelectric relay, a periodic checkup should be made every 6 months. The windows should be cleaned. All tubes should be tested, and weak or bad tubes should be replaced. Any extensive maintenance work should be done by the manufacturer.

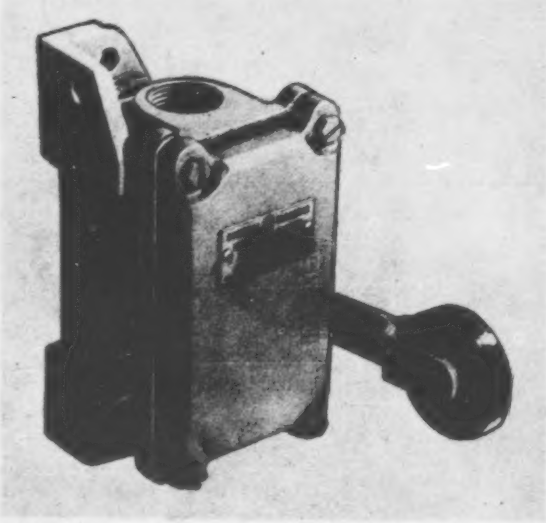
LIMIT SWITCHES

In certain applications the ON-OFF switch does not give enough control to ensure safety of equipment or personnel. A limit switch is incorporated in the circuit in order that operating limits are not exceeded.

The limit switch is installed in series with the master switch and the voltage supply. Any action causing the limit switch to operate will open the supply circuit.

One application of limit switches is in equipment that moves over a track. It is possible to apply power so that operation will continue until the carriage hits an obstruction or runs off the end of the track.

If limit switches are installed near the end of travel, an arm or projection placed on the moving section will trip a lever (as shown in figure 6-38) on the limit switch. The switch then opens the circuit and stops the travel of the carriage. This type of control is a direct-acting, lever-controlled limit switch. Another type, an intermittent gear drive limit switch, may be coupled to a motor shaft to stop action when a definite number of shaft revolutions is completed.



77.250

Figure 6-38.—Limit switch, roller actuator arm-operated.

FLOAT SWITCHES

A float switch (fig. 6-39 controls electrically driven pumps used to fill or empty tanks.

Construction

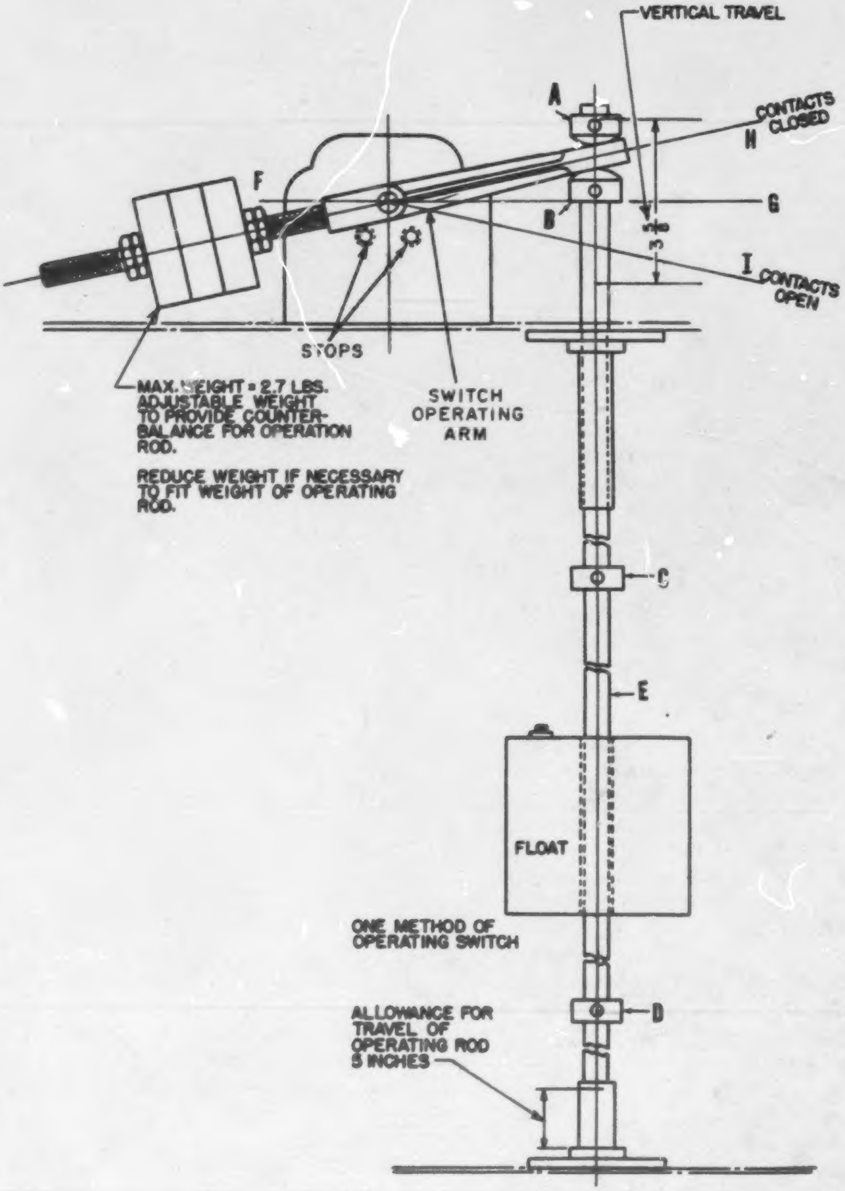
In a tank installation (fig. 6-39) the deck and overhead flanges are welded to the deck and overhead of the tank. The float guide rod, E, fits into the bottom flange and extends through the top flange. The float guide rod then passes through an opening in the switch operating arm. Collars A and B on the guide rod exert upward or downward pressure on the operating arm as the float approaches minimum or maximum depth positions. The switch operating arm is fastened to the shaft, which is coupled to the switch contact mechanism. Collars C and D on the guide rod are held in position by setscrews so that their positions can be changed to set the operating levels to the desired points.

As the float goes up and down, corresponding to the liquid level, it does not move the float guide rod, E, until contact is made with either collar. When the float comes in contact with either collar, the external operating arm of the switch is moved and the switch is operated.

Although the switch assembly is of rugged construction, it must be checked regularly for proper performance.

Maintenance

The switch contacts should be kept in good electrical condition. Determine the kind of


VERTICAL TRAVEL
A
CONTACTS CLOSED
H
F
G
B
3 5/8
I
CONTACTS OPEN
STOPS
MAX. WEIGHT = 2.7 LBS. ADJUSTABLE WEIGHT TO PROVIDE COUNTER-BALANCE FOR OPERATION ROD.
REDUCE WEIGHT IF NECESSARY TO FIT WEIGHT OF OPERATING ROD.
SWITCH OPERATING ARM
C
E
FLOAT
ONE METHOD OF OPERATING SWITCH
D
ALLOWANCE FOR TRAVEL OF OPERATING ROD 5 INCHES

77.116

Figure 6-39.—Float switch tank installation.

metal used for the contacts, whether copper or silver, and apply maintenance procedures outlined earlier in this chapter. Of course, contacts should never be cleaned while power is applied to the circuit.

Lubricants should not be applied to contact surfaces.

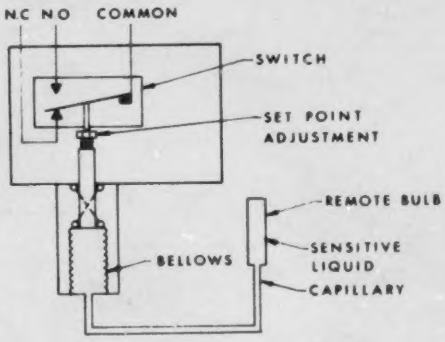
PRESSURE AND TEMPERATURE SWITCHES

Pressure and temperature controls have been grouped together because the switching mechanism is the same for both controls; the difference is in the sensor operation (fig. 6-40).

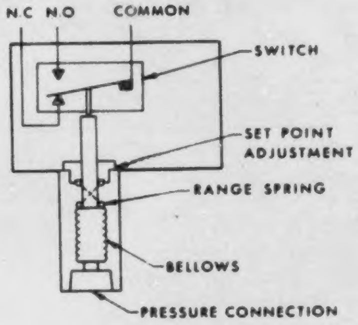
Pressure-controlled switches are operated by changes in pressure in an enclosure such as a tank. Temperature-controlled switches operate from changes in temperature that take place in an enclosure or the air surrounding the temperature-sensing element. Actually, both switches are operated by changes in pressure. The temperature element is arranged so that changes in temperature cause a change in the internal pressure of a sealed gas or air-filled bulb or helix, which is connected to the actuating device by a small tube or pipe. Temperature changes cause a change in the volume of the sealed-in gas, which causes movement of a bellows or diaphragm. The movement is transmitted by means of a plunger to the switch arm. The moving contact is on the arm, and a fixed contact may be arranged so that the switch will open or close on a temperature rise.

When the switch is used to control pressure, the temperature element is replaced by a tube that leads to the pressure tank. The pressure inside the tank then operates the switch mechanism.

Pressure or temperature controls may be used as a pilot device (fig. 6-41). The circuit operation is exactly the same regardless of the kind of pilot device used to control the circuit. To maintain more or less constant temperature or pressure, switch contacts are arranged to close when the pressure or temperature drops to a predetermined value and and to open when the pressure or temperature rises to the desired value. The reverse action can be obtained by changing the contact positions.



TEMPERATURE



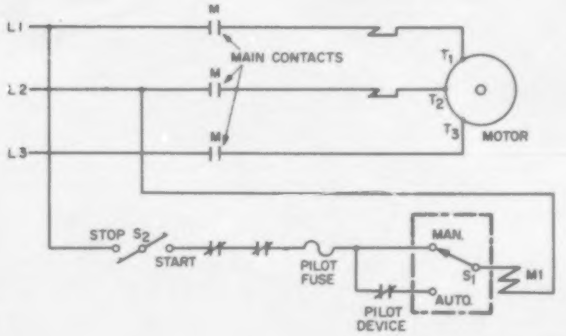
PRESSURE

73.298X

Figure 6-40. — Temperature and pressure-operated switch schematics.

The difference in pressure for contact opening and closing is the differential. The switch mechanism has a built-in differential adjustment so that the differential can be varied over a small range. Once set, the differential remains essentially constant at all pressure settings.

Each switch has a range adjustment that sets the point at which the circuit is closed. Changing the range adjustment raises or lowers both the closing and opening points without changing the differential.



77.118

Figure 6-41.—Representative pilot device control circuit.

Operating Adjustments

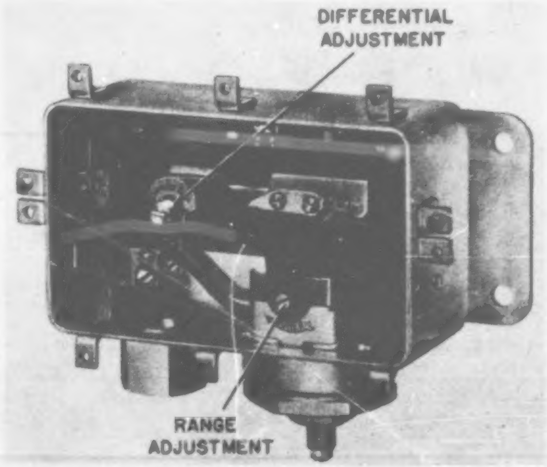
To set the operating range of the switch, turn the differential adjustment screw (fig. 6-42) counterclockwise against the stop for minimum differential. Bring the pressure to the value at which the circuit is to be closed. If the switch contacts are open at this pressure, turn the range screw slowly clockwise until the contacts close. If the contacts are closed when the desired pressure is reached, turn the range screw counterclockwise until the contacts open; then turn the screw slowly clockwise until the contacts close. These adjustments set the closing pressure.

The pressure (keep in mind that changes in temperature are converted to changes in pressure) is now raised to the point where the circuit is to be opened. When this point is reached, turn the differential screw slowly clockwise until the contacts open; this adjustment sets the opening pressure.

A later model pressure switch incorporates trip indicators and scales for pressure or temperature (fig. 6-43). Note its internal construction in figure 6-44.

Thermal Unit Probes

The bulb and helix units can be connected to the switch section (fig. 6-45). The bulb unit (see A in fig. 6-45) is normally used when liquid temperatures are to be controlled. However, it may control air or gas temperatures, provided the circulation around it is rapid and the temperature changes at a slow rate.



77.119

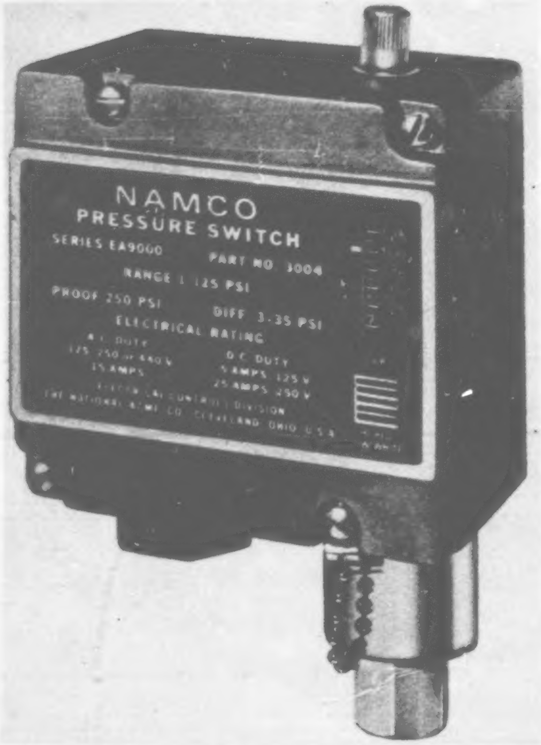
Figure 6-42.—Pressure-operated switch.

The helical unit (B in fig. 6-45) has been specifically designed for air and gas temperature control circuits. To be most effective, the thermal unit must be located at a point of unrestricted circulation so it can "feel" the average temperature of the substance that is to be controlled.

Some switches are stamped, WIDE DIFFERENTIAL. They are adjusted in the same manner described for the regular controls. However, because of slight design changes, it is possible to get wider variation in differential settings.

Maintenance

When adjusting temperature controls, allow several minutes for the thermal unit to reach the temperature of the surrounding air, gas, or liquid before setting the operating adjustments. After adjusting the operating range of pressure or temperature controls, check the operation through at least one complete cycle.



77.119AX
Figure 6-43.—Modern pressure switch.

If you find variation from the desired operating values, go through the entire procedure again and observe operation through a complete cycle.

ELECTRONIC TEMPERATURE CONTROL

Temperature variations of a wire wound resistor or thermistor type probe cause resistance changes detectable by a Wheatstone Bridge. A slight bridge imbalance is amplified and, in turn, energizes the output relay as shown in figure 6-46.

AUTOMATIC BOILER CONTROLS

The term "controls," when applied to boiler plants, refers to devices which control the water level and flow, steam pressure and flow temperature, draft, fuel feed, and combustion. Controls also provide safeguards in case of flame failure or water supply failure.

WATER LEVEL CONTROLS

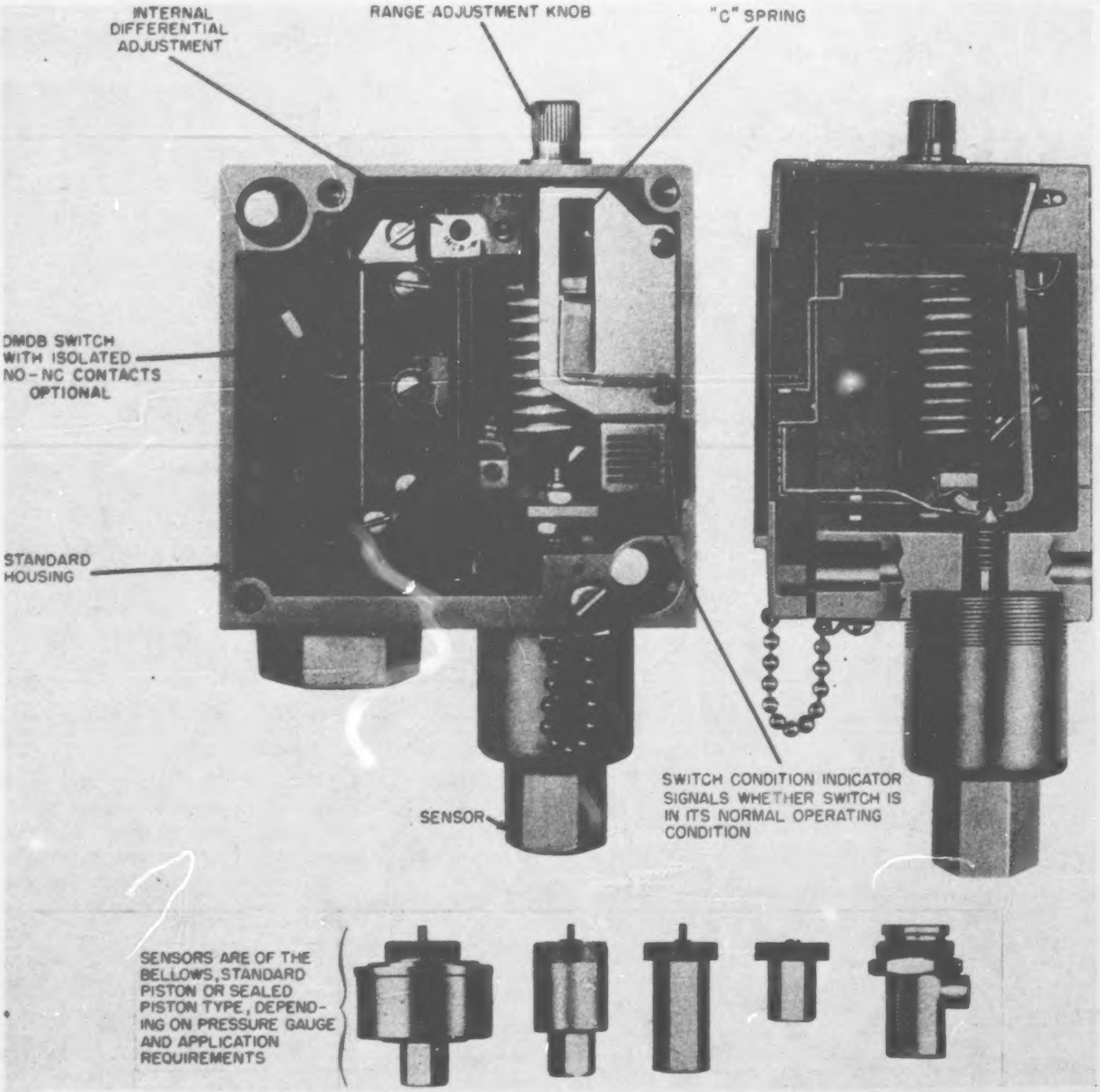
An imbalance in the amounts of fluid flowing into and out of steam generating equipment causes a change in the water level in the boiler, tank, or other vessel in the system. The change in level is detected by a level control or float control which actuates other devices that restore the balance or cut off the fuel supply if the water falls to a dangerous level. Two common types of water level controls are the electrode probe and the float.

Electrode Probe

The electrode probe operates the boiler feed pump and also protects the boiler against low water by securing the source of heat. An electrode assembly inserted at the top of the boiler has three electrodes of different lenghts which extend down to the water level of the boiler (fig. 6-47). Alternating current is supplied to the electrodes from a transformer in the water level relay. Should the water level recede below the longest electrode, a low water alarm horn sounds and the burner stops. The middle and shortest electrodes actuate the boiler feed pump, the shortest electrode stops the pump, and the middle electrode starts the pump.

Float

The other type of water level control, the simple float, rises and falls at the water surface. The float may be mounted in the boiler tank or in a separate float chamber. It is sometimes connected directly to a water intake control valve; it may, instead, operate a relay mechanism. A relay system has advantages over the float-valve connection in that the control device can be located at a considerable distance from the float and the water level can be controlled within closer limits.

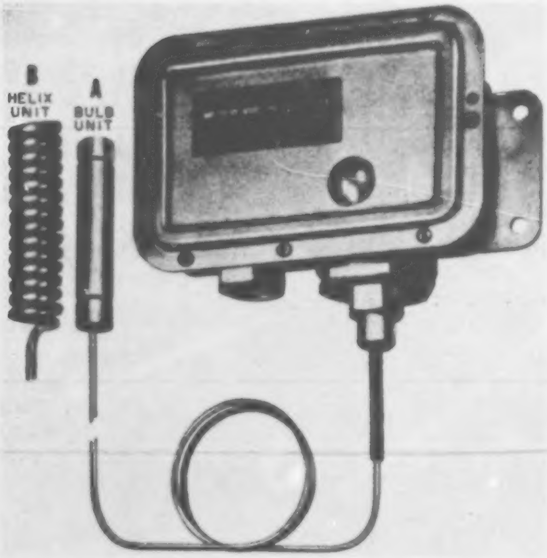

INTERNAL DIFFERENTIAL ADJUSTMENT
RANGE ADJUSTMENT KNOB
"C" SPRING
DMDB SWITCH WITH ISOLATED NO-NC CONTACTS OPTIONAL
STANDARD HOUSING
SENSOR
SWITCH CONDITION INDICATOR SIGNALS WHETHER SWITCH IS IN ITS NORMAL OPERATING CONDITION
SENSORS ARE OF THE BELLOWS, STANDARD PISTON OR SEALED PISTON TYPE, DEPENDING ON PRESSURE GAUGE AND APPLICATION REQUIREMENTS

77.119BX

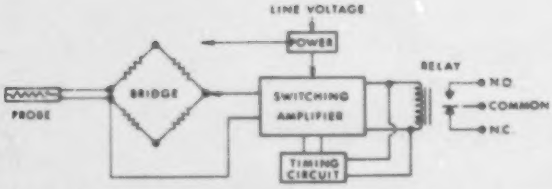
Figure 6-44.—Internal construction of a modern pressure switch.

PRESSURE LIMIT SWITCH

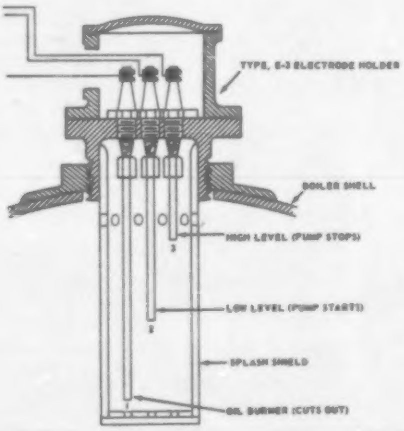
The boiler high-limit steam pressure is controlled by the pressure switch, sometimes called the Pressuretrol after a common trade name. The Pressuretrol is a part of the control system for automatic operation of steam generators. It is used in series with the low water cutoff and the burner control. A representative pressure switch is shown in figure 6-48. When there is sufficient water in


B
HELIX UNIT
A
BULB UNIT

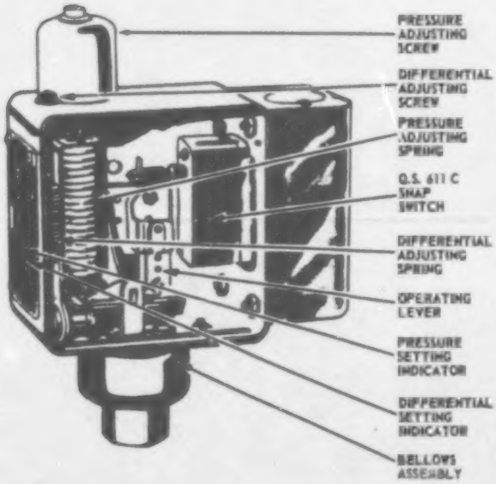
77.120
Figure 6-45.—Thermal units.


LINE VOLTAGE
POWER
BRIDGE
PROBE
SWITCHING AMPLIFIER
RELAY
N.O.
COMMON
N.C.
TIMING CIRCUIT

73.299X
Figure 6-46.—Electronic temperature control schematic.


TYPE, E-3 ELECTRODE HOLDER
BOILER SHELL
HIGH LEVEL (PUMP STOPS)
3
LOW LEVEL (PUMP STARTS)
2
SPLASH SHIELD
OIL BURNER (CUTS OUT)
1

75.299
Figure 6-47.—Water level electrode assembly.


PRESSURE ADJUSTING SCREW
DIFFERENTIAL ADJUSTING SCREW
PRESSURE ADJUSTING SPRING
Q.S. 611 C SNAP SWITCH
DIFFERENTIAL ADJUSTING SPRING
OPERATING LEVER
PRESSURE SETTING INDICATOR
DIFFERENTIAL SETTING INDICATOR
BELLOWS ASSEMBLY

75.300
Figure 6-48.—Pressure switch.

the boiler, steam is generated and acts upon the bellows. The bellows in turn operate a mercury (single-throw) switch or single-pole switch. When the steam pressure is below the high limit, the switch is closed and the current passes on to the burner control to start the fire cycle. When the high-limit steam pressure is reached, the Pressuretrol switch will open and stop the burner.

SAFETY COMBUSTION CONTROLS

Safety combustion controls are devices designed to shut down the burner and thus prevent flooding the furnace with oil in event of ignition failure or flame failure subsequent to initial ignition. These controls include the thermostatic type (stack switches and pyrostats), photoelectric type, and the photoconductive type.

Stack Switch (Thermostatic Type)

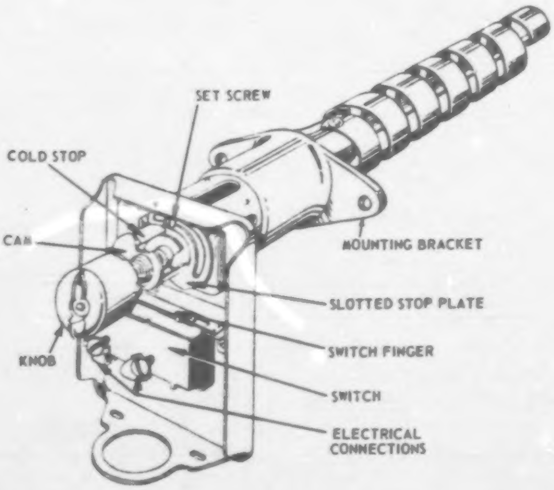
The stack switch consists basically of a bimetal helix, a mounting frame, a shaft carrying a contact-making mechanism, and an electric switch. A stack switch is shown in figure 6-49. The helix is connected to the mounting frame at one end and a rotating shaft at the other. The stack switch is mounted on the boiler smoke stack or hood with the helix protruding into the path of the combustion gases. The shaft, which is inside the helix, turns a cam which pushes a switch finger which closes a switch. The switch is wired into the burner electric circuit so that no current is supplied to the burner when the contacts are open, except through the Protectorelay (explained later) to permit initial ignition. When there is no heat in the boiler, the switch contacts are open. When the burner is ignited, the helix expands due to the increase of the stack temperature and causes the shaft to rotate and close the contacts. Unless the stack temperature decreases, the contacts remain closed, permitting operation of the burner. In the event of a flame failure, the helix contracts due to the falling stack temperature and causes the shaft to rotate in the reverse direction. This opens the contacts and shuts down the burner.

Photoelectric Combustion Controls

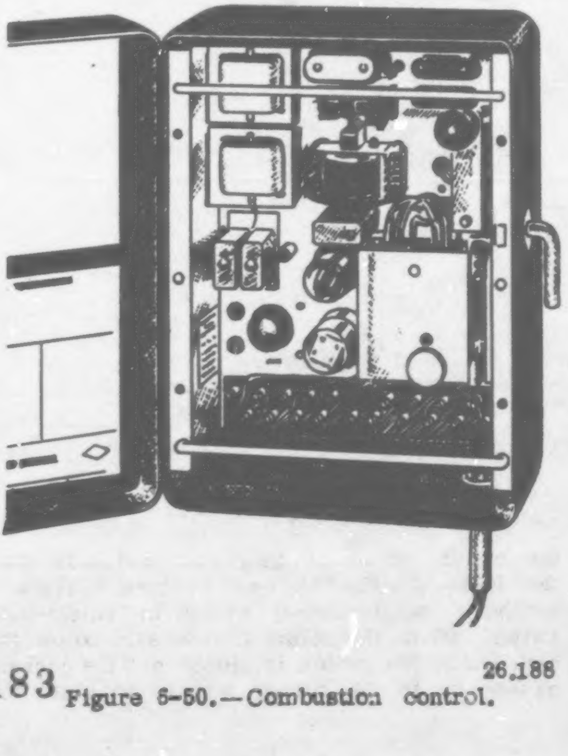
A photoelectric control consists basically of a photoelectric cell, an amplifying unit, and a relay. These controls operate by the luminosity of the flame acting upon the photoelectric cell which makes a contact within itself when light rays impinge upon it. The amplified current of the photoelectric cell operates the relay which is wired into the burner control circuit. The relay completes the burner circuit when the flame is established and breaks the burner circuit in event of flame failure.

Photoconductive Combustion Control

The photoconductive control (fig. 6-50) serves the same function as the photoelectric type. In the photoconductive type, resistance



75.301
Figure 6-49.—Stack switch.



26.188
Figure 6-50.—Combustion control.

of the cell varies when exposed to infrared radiation. The associated electronic circuit of the control amplifies only the pulsating frequency peculiar to flame radiation. The control thus discriminates between flame and hot refractory or other source of infrared.

PROTECTORELAYS

A Protectorelay is an electromagnetic switch usually consisting of a signal amplifying circuit, three relays, and a thermal safety switch. A schematic of a Protectorelay is shown in figure 6-51. Protectorelays are used on many firetube type boilers arranged for automatic operation to perform the following functions:

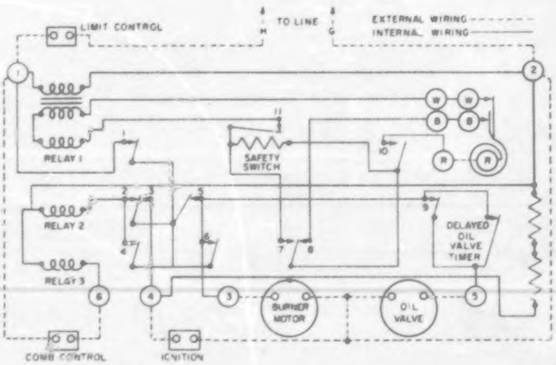
1. Provide interlock between burner and burner controls.
2. Provide a temporary circuit for starting burner and ignition.
3. Effect automatic shutdown and restart of burner in response to pressure regulating and feed water regulating controls.
4. Effect emergency shutdown of burner in response to safety combustion controls.
5. As an integrated part of the boiler control circuit, tie together the burner operating controls and the safety combustion controls.

MAINTENANCE

Because of the wide variations in the design of the boilers which the SEABEES operate and maintain, it is impractical to prepare general operating and maintenance instructions for all the types in use. Therefore, the Navy requires that manufacturers include this information in their technical manuals which are provided with each boiler. Specific attention should be paid to maintaining automatic regulating control and safety devices in proper operating condition. Undetected failure of these devices may lead to a major casualty, injury to personnel, and damage to equipment.

TROUBLESHOOTING HINTS

There are many hints in troubleshooting that will make it easier for you to find trouble when boilers are not operating properly. The following outline contains some of the common causes of ignition and flame failure in boilers.



26.189

Figure 6-51.— Protectorelay schematic.

A. Ignition Failure
1. Dead transformer.
2. Broken high-voltage leads.
3. Cracked electrode insulator.
4. Carbon deposits on electrodes or insulators.
5. Incorrect electrode setting.
6. Malfunctioning programming control cams.
7. Faulty ignition cable connector.
8. Solenoid valve fails to open.
9. Water in oil.
10. Dirty or clogged burner tip.

B. Flame Failure
1. Dirty glass in photocell.
2. Abnormal ambient temperature. (Refer to combustion safeguard in boiler technical manual.)
3. Bad electron tube in combustion safeguard control.
4. Bad electron tube in photocell.
5. Damaged cell.
6. Loose connection on photocell.
7. Out of oil or water in oil.
8. Clogged nozzle.
9. Broken belt (V-belt drive).
10. Broken pressure regulator spring.
11. Dead solenoid valve.

CHAPTER 7

SHOPWORK

It is important for you to understand the overall shop operation, shop repair equipment, and be thoroughly familiar with the safety rules you are required to observe while in the shop. Why? Such knowledge will enable you to perform your duties correctly and safely.

One of your more important duties in the shop is motor and generator repair and maintenance. You will also be required at times to troubleshoot and repair a variety of appliances, such as window air-conditioners, washing machines, and the like. This chapter provides rather detailed information on motor and generator repair and maintenance, and briefly explains some typical schematics of appliances to guide you in troubleshooting and repairing them.

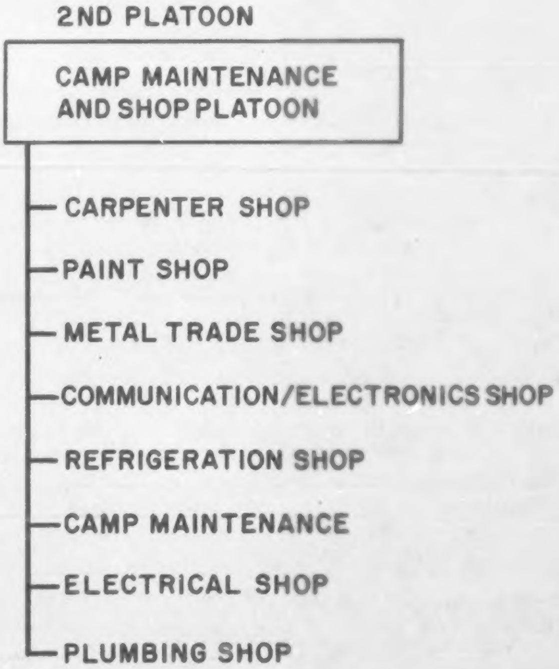
SHOP ORGANIZATION

The objective of the shop organization is to provide prompt return of defective equipment to an operating or operable condition. Shops vary in size, scope of operation, number of personnel, and tools and equipment. In Naval Mobile Construction Battalion, "B" company is responsible for the camp shops and maintenance platoon. The organizational setup for this platoon is shown in figure 7-1. The platoon commander provides shop services for all projects and the maintenance of the camp.

Shop rules, regulations, and procedures are usually posted either on the bulletin boards or adjacent to equipment. BE SURE TO FOLLOW ALL THE RULES AND REGULATIONS. They were designed for YOUR safety.

Usually, a senior Construction Electrician supervises shop operations. He exercises overall supervision of shop activities, coordinates the efforts of its maintenance personnel, and is responsible for the successful completion of the shop's assigned mission.

The electrical repair shop is the general headquarters at a Navy base for the repair and overhaul of electrical equipment. In general, smaller items of defective equipment will be sent to the shop for repairs, but you may also go to various places on the base to repair equipment when it is not practicable to move it to the shop. The electric shop is also a storeroom for parts and some material. Most of the new construction wiring material will be delivered



73.391
Figure 7-1.—"B" company, 2nd platoon organizational structure.

directly to the jobsite, especially the heavy items such as conduit, panels, and wire. Parts for the repair of tools and equipment, however, will normally be stored in the shop.

In the shop you will generally be working under a Chief or a First Class Construction Electrician, and you will receive instructions from him concerning the use and storage of equipment and tools. It is to your advantage to learn as much as possible about these tools, so that you will know the correct tool for the job at hand, and will be able to operate it safely and skillfully.

TOOLS AND EQUIPMENT

The amount and type of electrical equipment to be maintained and new construction to be done will vary from base to base, but there are certain basic tools which you must have to make the usual shop repairs and to keep the electricians on the various jobs supplied with the tools appropriate to the job. The basic tools include pliers, rules, screwdrivers, hammers, and other such small tools; also larger tools such as pipe benders for rigid and thinwall conduit, hydraulic benders for the larger pipe, threaders for both small and large pipe, pipe vises, reamers, fish tapes, and pullers.

All of these tools should have designated racks or bins for storage when not in use on the jobs. A system is usually set up for checking the tools in and out. The shop man should know, or be able to find out from his records, where all tools are at all times.

A special bin should be used for the testing equipment. These instruments are very delicate, and any rough handling may easily throw them out of adjustment. Do not put any other tools in the same bin with the testing instruments.

It is a good idea to examine all tools when they are issued and again when they are checked back into the shop. Any tool found in bad condition should be put aside until it can be repaired.

A preventive maintenance file of the larger tools and items of equipment should be kept in the electric shop. This file shows when each piece of equipment or power tool is due to be checked, greased or oiled, and its condition at the time of each inspection. It is most important that the file be kept up to date. It has been proven that preventive maintenance carried out properly will reduce the repairs on tools and other equipment 59 percent or more. Proper maintenance also saves time which would have been lost due to equipment breakdown.

MATERIAL AND PARTS

The shop man usually sets up and maintains a system for storage of parts and material which will be kept in the shop. A good method is to prepare a set of file cards showing the minimum amount of each item needed, the amount on hand, and location of storage area. As materials and parts are received, they are stored in the places designated for those particular items, and the amounts received are added to the inventory on the file cards.

Repair parts, especially bearings, should never have the wrapping removed prior to the time of installation. Unwrapped bearings accumulate dust and grit which will ruin the bearing. Also, unwrapped parts are more easily broken than the ones left in the containers in which they are received.

When parts are used, the items are deducted from the inventory. If you have occasion to assist in setting the minimum number of repair parts to be kept on hand, take into consideration the length of time needed to get these parts after the requisition is forwarded to the supply department. At some overseas locations this period may be from 3 to 6 months.

In addition to the parts inventory file, maintain a file of all instruction manuals received with the various pieces of equipment. A repair job is always simpler if you have the instruction manual for the piece of equipment being worked on. If you don't have a system for filing the manuals, a great deal of time may be lost while you hunt through a stack of papers for the needed item. A desk drawer does not make a good filing cabinet.

ELECTRICAL SHOP SAFETY

Many of the safety rules described in this section apply to you wherever you are working—that is, their application is not limited to work in the electrical shop. However, the following rules have particular application to work in the shop, and for that reason are listed in this chapter.

Housekeeping Rules

The use of sound common sense can prevent accidents to personnel, and loss of, or damage to, material or equipment. Keep the working spaces safe, both for the men working there and for any personnel who may pass through or nearby. Carefully observe the following safety rules:

Place tools and materials where they cannot fall on anyone, and where no one is likely to stumble over them. Where material must be piled, have the pile neat and compact.

Never lean tools or materials against a wall or other support that might give under the additional weight. Do not lean them against any support where they could be jarred loose.

When you leave a working space for any considerable time, store tools and materials in an appropriate place.

Wipe up any grease or oil spots in the working areas.

Fire Prevention

Deposit all flammable waste (especially greasy waste, oil-soaked rags, or paint-covered cloths) in approved metal cans equipped with self-closing covers, and see to it that these cans are emptied daily.

Although gloves are required for many jobs done by a Construction Electrician, you should NOT wear them while filling furnaces or torches, or when handling gasoline-soaked rags.

Do not fill a furnace or torch while it is hot, and do not start a blowtorch until the gasoline in the priming cup is almost all consumed.

Place furnaces and blowtorches where they will not be in a position to ignite surrounding material. Use a metal plate as a foundation if necessary. Never leave a lighted furnace or a blowtorch unattended.

Avoid dropping hot solder on combustible material.

Release the air pressure from the gasoline tanks of furnaces or torches after use, and before putting them away.

Keep flammable liquids in approved safety containers, and stored in approved areas.

Use canvas or asbestos shields to protect combustible surfaces in the vicinity of welding operations. Keep fire extinguishers (water or soda-acid) near at hand, and maintain a watch for sparks that might lodge in cracks or other out-of-the-way places.

Do not use gasoline as a cleaning agent. For safety, use a low-hazard solvent.

Never use a flammable liquid for starting fires in rubbish or in salamanders (portable stoves).

Keep driveways, doors, aisles, and other approaches clear, so that there will be no obstacles to bringing in fire apparatus or equipment if that becomes necessary.

Notify the base fire department at once when a fire extinguisher has been used, so that it can be recharged or replaced.

Protective Clothing and Equipment

The Construction Electrician, like any other person working around machinery, should be careful never to wear rings or other jewelry; to make sure that ties, loose sleeves, or other loose clothing is not subjecting him to risk of entanglement; to avoid wearing zippered clothing (or, if zippers are unavoidable, to be sure they are covered); to avoid wearing caps with celluloid (highly flammable) visors; and to wear gloves and goggles whenever necessary.

Always wear rubber gloves and goggles when working on electrical equipment which may arc. In this connection follow a general rule of keeping your body as far away as possible from circuit breakers, or other parts where arcing may occur.

Ventilation

Ventilation of the working space is essential to your health. Fumes must be carried off before they cause physical injury, or (in some cases) an explosion.

Handling Acid

Carelessness in the handling of acid is a frequent cause of acid burns. The pain and damage caused by an acid burn doesn't require explaining. When mixing an electrolyte (which consists of an acid diluted with water), ALWAYS POUR THE ACID INTO THE WATER, never the other way around. A small amount of water poured in pure acid will usually produce a boilup. Pour acid into water S-L-O-W-L-Y, to prevent excessive heating and agitation.

Grounding of Equipment

Mention must be made of the importance of knowing how to ground various types of equipment and appliances, so that personnel will be protected against the danger of electrical shock. At one time it was the custom to ground only those machines and appliances which operated from supply circuits of more than 150 volts. Standard procedure now, however, requires the grounding of any equipment operating from a voltage of 50 volts or more. Grounding in the less-than-50-volt range is at the discretion of local authority. You should ascertain what the policy is at your station, base, or activity.

The type of equipment which must be grounded obviously includes heavy-duty equipment such as X-ray machines, transformers, and generator station equipment. Motors must have their frames grounded. All noncurrent-carrying metal parts, such as metallic conduit, cable armor, switch boxes, and so on, must be kept as close as possible to ground potential (0 volts) by providing a low resistance to ground.

As has already been mentioned elsewhere, water pipes make excellent ground connections, but the connection should be made on the service side of the water meter (that is, on the street side). Where pipes on the service side are not attainable, you must use ground rods. NEVER ground to steam pipes, or to fire sprinkler systems which may be disconnected.

The following relatively low-voltage items must have their cases or enclosures grounded:

- Most shop tools, such as drills, floor polishers, sanders, grinders, saws, soldering pots, and soldering irons.

- Most office machines, such as addressographs, mimeograph machines, paper cutters, typewriters, dictating machines, and calculators.

- Heavy appliances such as refrigerators, stoves, washing machines, ironers, and sewing machines.

- Galley equipment such as broilers, grills, toasters, food mixers, coffee grinders and urns, and food freezers.

- Appliances in living spaces, such as radios, record players, TV sets, extension lights on portable cords, and desk lamps enclosed in metal.

Navy safety precautions thus require the grounding of equipment which may be operating on relatively low voltage. The ground connections must be not only electrically adequate, but also mechanically secure. All equipment and appliances should be checked for proper ground at regular intervals of not more than 1 year.

The man in charge of the repair shop should be able to supply you with necessary safety instructions and notices, or at least to inform you of what the station's overall safety program requires of you.

REPAIRS TO GENERATORS AND MOTORS

Except for the special procedures required in the rewinding of armatures and stators, repair processes are very much the same for generators and motors. Regular inspection, cleaning, and lubricating at the station where the electrical equipment is in use will usually keep this equipment in good service. If the operator watches the performance of new motors and generators until he is sure that their operation is satisfactory, and if he gives extra care to the inspection and cleaning of old equipment, there will be less burden on the repair shop.

However, there will be cases where the machine operators have failed to follow regular schedules of maintenance. In this event, you will find it advisable to make a preliminary inspection, to determine if neglect rather than mechanical breakdown is causing the trouble. Sometimes the simple procedure of removing foreign matter (iron dust, abrasive particles), of resetting brushes, or of lubricating bearings, will restore the machine to satisfactory operation.

DISASSEMBLY AND REASSEMBLY

When it becomes necessary to disassemble and reassemble a large motor or generator, follow the procedures outlined in the manufacturer's instruction book, exercising care to prevent damage to any part of the machine. The machine rotors should be supported, while being moved or when stationary, by slings or blocking under the shaft, or by a padded cradle or thickly folded canvas under the core laminations. To lift the rotor, rope slings (separated by a spreader to prevent the slings from coming in contact with the a-c rotor or d-c armature coils) should be placed under the shaft, clear of the journals. If construction of the shaft provides no room for a sling except around the journals, they must be protected with heavy paper or canvas before the sling is applied. When the whole unit (stator and rotor) is to be lifted by lifting the stator, the bottom of the air gap must be tightly shimmed unless both ends of the shaft are supported with bearings. On very large generators where the ends of the shaft are not supported by bearings during lifting, the rotor should be removed first.

It is easily possible, by rough handling or careless use of bars or hooks, to do more damage to a machine during disassembly and assembly than it will receive in years of normal service.

Never be hasty or careless in disassembling a generator or motor. Handle the delicate components with care, so as not to damage them, or to create the need for additional adjustment. Use the proper tools; label the parts as you dismantle them, and store them in an orderly arrangement in a safe place. Write down the necessary information so that you will have no trouble in reassembly.

If you have done a careful job of breaking down a machine into its components, the process of reassembling it should be the reverse order of taking it down.

When you remove end bells, punchmark the frame and mating end bells as indicated in figure 7-2, using a different mark for each end. Later on, these marks will facilitate reassembly. Remove fastening screws, bolts, and ball bearing cap plate screws. Use a rawhide or rubber mallet to part the end bells from the frame. The armature or rotor will now rest on the stator.

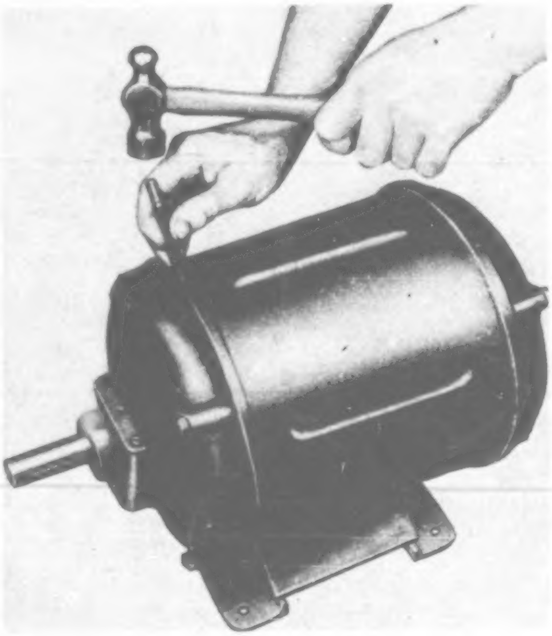
Protect the windings, if necessary, by inserting thin strips of waxed wood in the gap between rotor and stator. Record the connections of all internal mechanisms and parts.

Clean the end bells with a brush and an approved solvent. Check them for cracks, burrs, nicks, and excessive paint, as well as for dirt.

Procedures for removing BEARINGS vary according to the type of end bell and bearing assembly. Figure 7-3 illustrates a simple method of removing a sleeve bearing by first selecting and placing a sleeve-bearing arbor on the bearing and applying pressure with a hydraulic press. In figure 7-4, the bearing is a ball bearing. It is being removed, not by arbor plates, but by a hook type puller.

Never remove the bearings unless they are in poor condition, or unless they must be removed to allow for removal of the end bells. If you are taking off a ball bearing, and plan to use it again, be careful to apply pressure to the inner race only. If pressure has been applied to the outer race, you will have to discard the bearing.

Never use a cleaning solvent on a sealed or a semisealed ball bearing. Store these bearings in a clean piece of waxed paper, till you are ready to use them.



73.223

Figure 7-2.—Marking a motor frame and end bell.

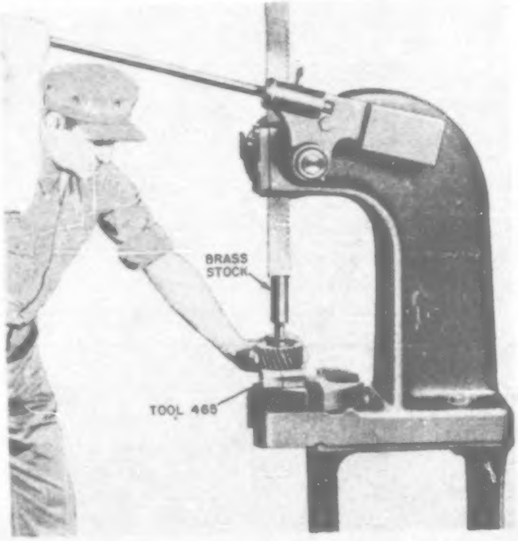


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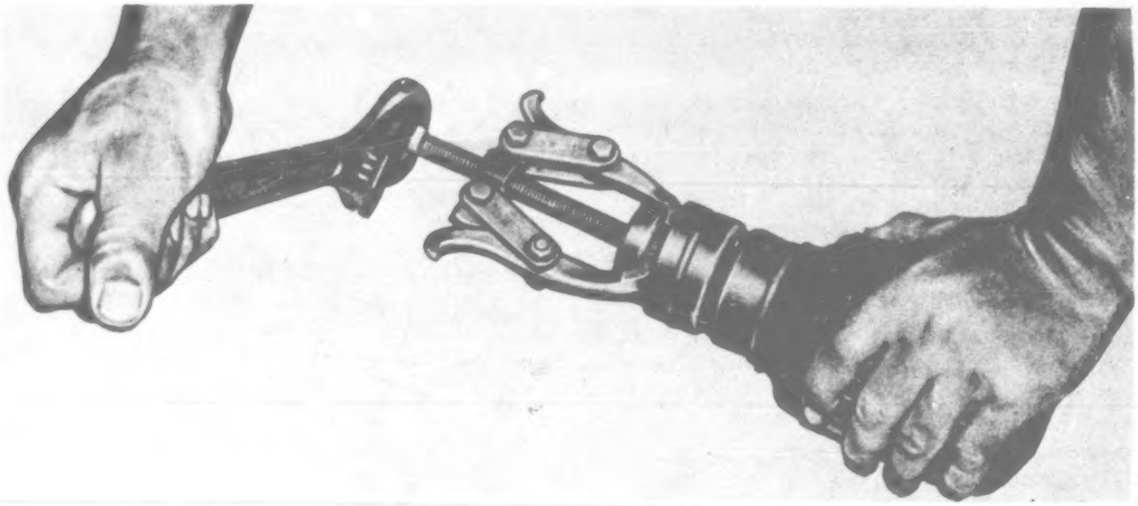
Figure 7-3.—Removing a sleeve bearing.



73.225

Figure 7-4. — Removing a ball bearing with a bearing puller.

If it is necessary to remove BRUSHES, take the precaution of recording angle and placement of the brushes and brush rigging, and clearance between brush holder and commutator (or slip rings). As a general rule, it is enough to place the brushes in the raised position. Remove brushes only when this procedure is necessary to give access to other parts of the unit.

Always record the connections of INTERNAL SWITCHES before removing them. Make a note of the thickness of fiber washers; tag the parts, and wrap them in waxed paper. Do not attempt to dress badly burned contacts, or to repair any charred, cracked or broken parts.

You must take particular care in removing ARMATURES AND ROTORS, to avoid damaging them. Protect yourself, too, by wearing canvas gloves while handling the shaft, to avoid getting cut on the keyways. Support the armature or rotor by its shaft, whenever possible, and do not allow its weight to rest on the commutator, coils, or rings. Figure 7-5 shows the proper method of supporting a small armature as you remove it from a motor or generator frame. Never roll or slide an armature on the bench or floor, since you might easily damage insulation or laminations.

Before removing POLE PIECES, record the relative positions of field coil assemblies, and the distance between pole surfaces. Tag the liners found between pole pieces and field frame to show type, thickness, and space occupied.

In unscrewing the slotted head screws, use the proper size and type of screwdriver. On hexagon-shaped head bolts, use the proper size and type of wrench. Any screw with a thread that is burred or stripped must be replaced. Lift the pole piece out carefully, so as not to damage adjacent coils.

Once the generator or motor has been taken down, you can make the necessary repairs to the component parts. The more usual types of repair are discussed in the following paragraphs.

COMMUTATORS

Good commutation requires satisfactory electrical and mechanical contact between brushes and commutator, or between brushes and collector rings. Excessive sparking about the brushes, commutator bars, or collector rings is usually an indication of poor commutation.

Poor commutation may be caused by pitted surfaces, the wrong type of brush, incorrect tension or alignment of the brush, unbalance of the armature and rotor, or wear from long use. The surfaces of the commutator and of the collector rings may be streaked and gummy because of oil vapor, oil, or grease. A blue or green tint to the copper may indicate the presence of chlorine or sulfur fumes.

Check the bars for burned condition, and for any irregularity or looseness. Check for high mica, or pitted condition. With the machine in motion, check the commutator bars for undue vibration.

Cleaning of commutator bars and collector rings should be done with a lint-free cloth moistened with an approved solvent. Polishing is done with the machine in motion. Canvas or hard cloth wound and taped around a stick can be held against the commutator, or the polishing can be done by applying a light load for several hours, increasing the load gradually as brush contact improves. Never use a lubricant either during or after polishing.

Irregularities in the collector rings or in the commutator bars can be corrected by grinding the surfaces with a commutator stone. This type of dressing tool is illustrated in figure 7-6. Where the irregularities are pronounced, a tool-type resurfacer must be used. Whichever device is used, the commutator or collector rings should be at operating temperature. Therefore, do the grinding just after the machine has been on-load.

If you use a commutator stone, revolve the commutator to its rated speed, and apply the stone. After a few minutes, the surface of the commutator will be bright, except for the flat spots and the burned edges. Keep applying the stone until these dark spots become bright, showing that they are even with the rest of the commutator. However, be careful not to remove more copper than is absolutely necessary.

Grinding resurfacers are often equipped with a vacuum cleaner arrangement fitted to the stone. Unless such an arrangement is available, to catch the dust, you will have to place a protecting cloth hood or heavy paper over the ends of the windings.

Turning Down Commutators

When a commutator has become pitted or rough and cannot be dressed with a dressing

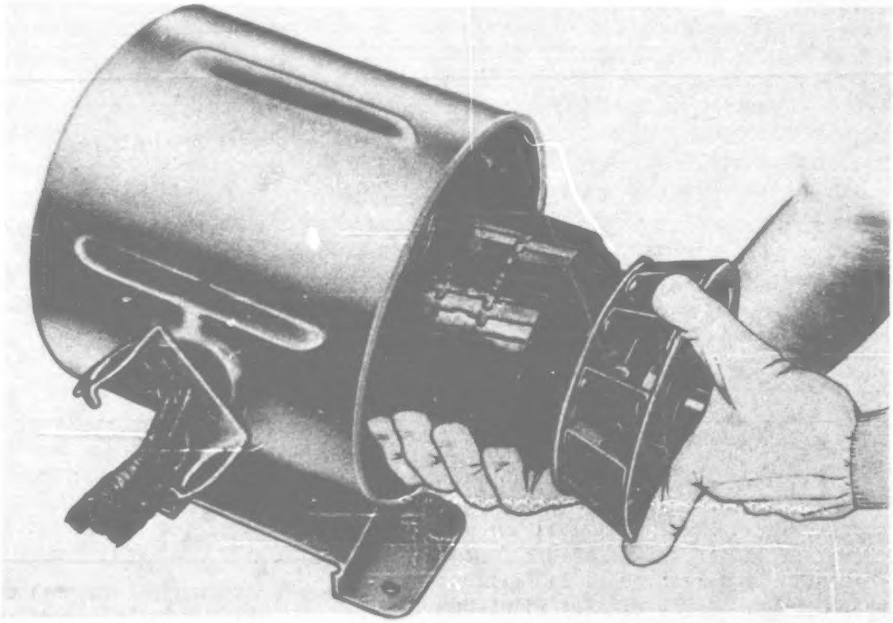


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Figure 7-5. — Removing a small armature from a motor frame.

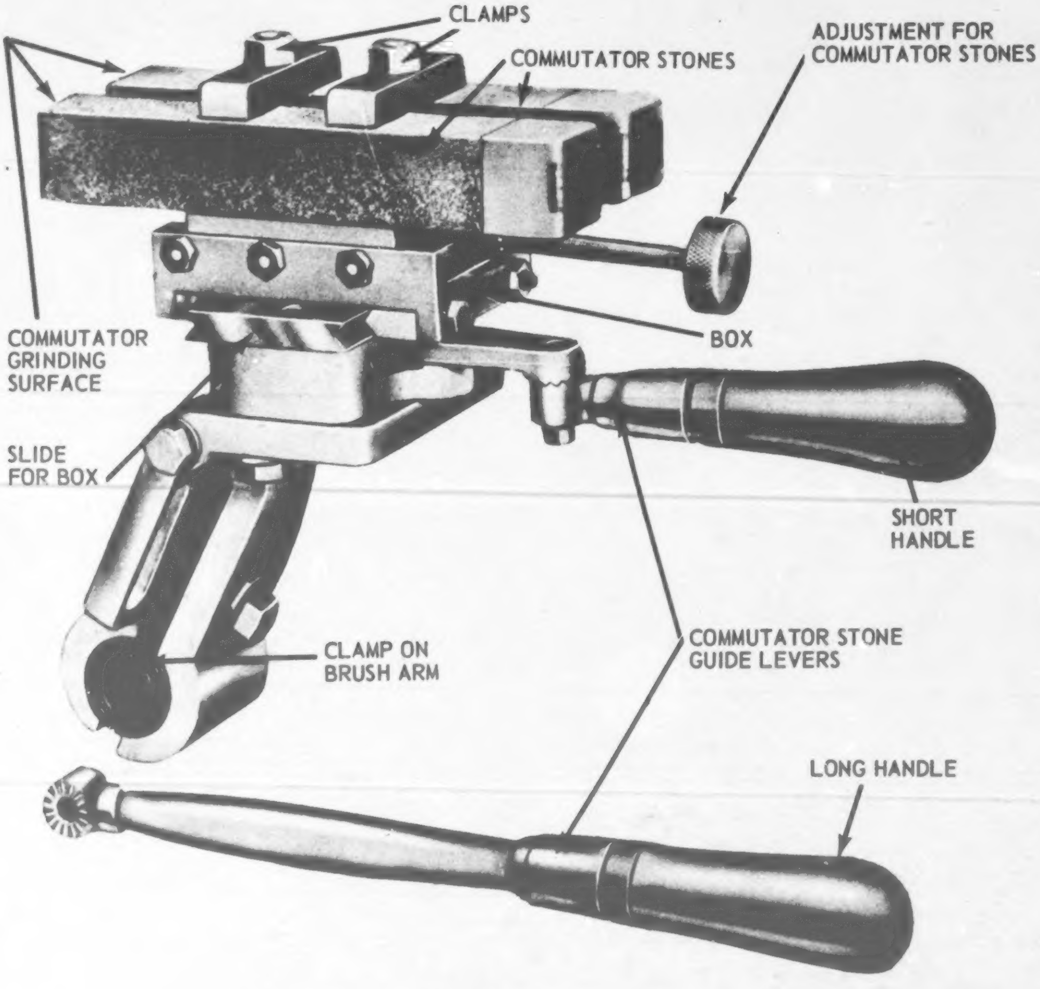
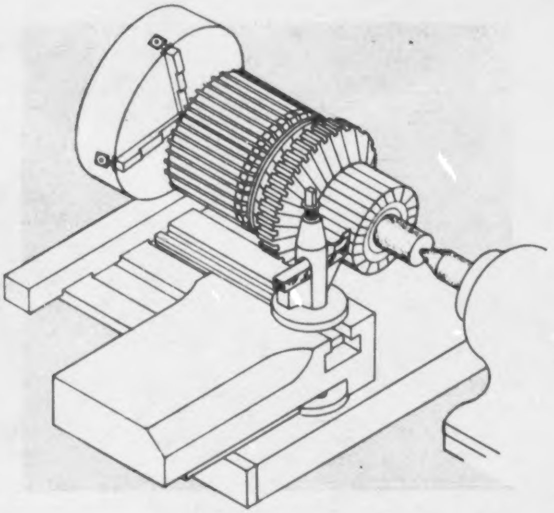

CLAMPS
COMMUTATOR STONES
ADJUSTMENT FOR COMMUTATOR STONES
BOX
COMMUTATOR GRINDING SURFACE
SLIDE FOR BOX
SHORT HANDLE
CLAMP ON BRUSH ARM
COMMUTATOR STONE GUIDE LEVERS
LONG HANDLE

Figure 7-6.—Commutator dressing stone tool. 73.227X

stone, it will be taken to the shop to be turned down in a lathe. Normally, this work will be performed by someone in the machine shop or mechanic shop, as lathes are seldom supplied to the electric shop because of the cost of the machine and the infrequency of its use. Usually in a Construction Battalion the heavy equipment shop will be equipped to do this type of work, or on a large base the public works machine shop will be equipped to handle it. Usually, the personnel in charge of these shops will not want an electrician, relatively inexperienced in lathe work, using a lathe, but prefer to assign an operator to the machine.

However, circumstances may require that an electrician run the lathe himself, and the steps in turning down a commutator are therefore explained here.

Figure 7-7 shows an armature centered in a lathe. First make sure that the armature is in good repair, and is approximately balanced. Place masking tape around the commutator risers, to prevent loose copper from working down inside the coil leads between armature wiring and commutator. Support the armature in the lathe, and make the cuts with a diamond-point cutting tool.



77.74

Figure 7-7. — Truing commutator by turning.

Because there is a certain give, or elasticity, to the support, a heavy cut may result in the cylindrical shape of the commutator being impaired. Again, a heavy cut can cause the turning tool to twist the commutator bars, and to make deeper cuts at one end than at the other. Take light cuts, therefore, even though more cuts will thus be necessary.

The lathe must be capable of turning the part to be ground at exactly its rated speed; if the cutting is done at a lower speed, any slight unbalance will cause the commutator to turn eccentrically, when run at rated speed. The usual cutting speed is 100 ft per min (fpm), which is 1200 in. per min (ipm). The feed should be about 0.01 in., and the depth of the cut should not exceed 0.01 in.

The procedure for changing fpm to revolutions per min (rpm) is as follows. First determine the circumference in inches of the commutator by measuring with a cloth tape, or by measuring the diameter and multiplying by 3.1416. Divide the result into 1200 to obtain the number of rpm required for a cutting speed of 100 fpm.

For example, suppose you have an armature with a 6-inch commutator diameter. Multiply this measurement by 3.1416 and you get a circumference of 18.85 inches. Divide this into 1200 and you get 63.66 rpm which rounds off to 64 rpm.

Insulating mica protruding from the slots between the commutator bars can cause wear, streaking, and breaking of the brushes. Remove this high mica by undercutting it to a depth of between 3/64 and 1/16 inch below the level of the commutator bars with a power-driven flexible shaft undercutter, after first removing the brush rigging. If a power-driven tool is not available, use a slotting tool, or else make a cutter by removing the teeth from a hacksaw blade and forming one end. The straight end, taped, will serve as a handle. Figure 7-8 shows properly and improperly undercut commutators.

Do not use lubricant, and do not cut too deeply. After removing the high mica, smooth out all burrs and polish the commutator with a commercial burnishing stone or hardwood block shaped to the curvature of the armature. The block is pressed hard against the surface of the commutator while the machine is running.

Poor balance in an armature can cause commutator failure. Detach the armature from the machine, and rest the shaft ends on V-blocks. For a ball-bearing-supported armature, let the bearings remain on the shaft, and check the commutator with the shaft on V-blocks. The surface on which the V-blocks rest must be perfectly level in every case. To check for concentricity, use a dial gage mounted on a brush holder with the contact tip of the gage contacting the top of the brush and rotate the armature.

Commutators with peripheral speeds of approximately 5500 fpm should be concentric to within 0.001 inch. For commutators with peripheral speeds of about 9000 fpm, the allowable tolerance is only 0.0005 inch.

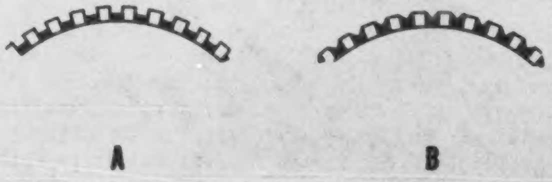


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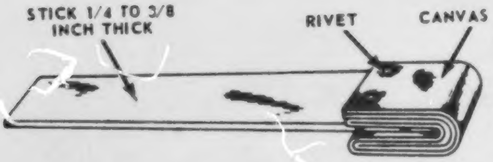
Figure 7-8. — (A) Commutator properly undercut; (B) Commutator improperly undercut.

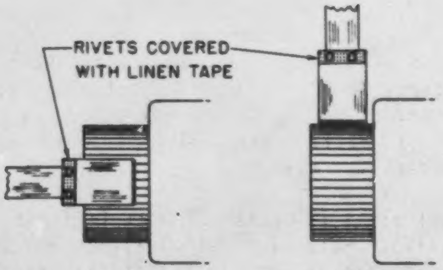


1.54.1
Figure 7-9. — Canvas wiper.

A check should be made on the air gaps at commutator poles, and at main poles, to determine if there is any wear or misalignment. You take the air gap measurement by setting a reference point on the armature (or rotor), and revolving it to measure four points on the stator (or the field frame) with reference to it. An equally satisfactory method is to choose your reference point on the stator or field frame, and revolve the rotor or armature to measure four points on the latter with reference to the stator point.

Correct tension on the commutator is usually determined at the time of manufacture. Tightening the commutator will not align the bars in their original position, and if the commutator becomes too tight, some of the bars may buckle. Making ringbolts and locknuts too tight may result in pressing the V-ring through the mica insulation, thus short circuiting the bars.

After being used approximately two weeks, the commutator of a machine should develop a uniform, glazed, dark brown color on the places where the brushes ride. If a nonuniform or bluish colored surface appears, improper commutation conditions are indicated. Periodic inspections and proper cleaning practices will keep commutator and collector-ring troubles at a minimum.



1.54.2
Figure 7-10. — Using the canvas wiper on a commutator.

Cleaning

One of the most effective ways of cleaning the commutator or collector rings is to apply a canvas wiper while the machine is running. The wiper can be made by wrapping several layers of closely woven canvas over the end of a strong stick between one-fourth and three-eighths inch thick (fig. 7-9). The canvas may be secured with rivets if they, in turn, are covered with linen tape to prevent the possibility of their contacting the commutator. When the outer layer of canvas becomes worn or dirty, it is removed to expose a clean layer. The wiper is most effective when used frequently. On large generators, it may be desirable to use the wiper once each watch. When using the wiper, exercise care to keep from fouling moving parts of the machine. The manner of applying the wiper to a commutator is illustrated in figure 7-10.

When machines are secured, a toothbrush can be used to clean out the commutator slots, and clean canvas or lint-free cloth may be used for wiping the commutator and adjacent parts. In addition to being cleaned by wiping, the commutator should be periodically cleaned with a vacuum cleaner or blown out with clean, dry air.

A fine grade of sandpaper, No. 00, may be used to clean a commutator that is only slightly rough, but not out of true. Sandpapering is recommended for reducing high mica, and for finishing a commutator that has been ground or turned. The sandpaper, attached to a wooden block shaped to fit the curvature of the commutator, is moved slowly back and forth across the surface of the commutator while the machine is running at moderate speed. Rapid movement or the use of coarse sandpaper will cause scratches. Emery cloth, emery paper, or emery stone should never be used on a commutator or collector ring.

COLLECTOR RINGS

Collector rings (slip rings) require the same careful attention as the commutator. Out-of-round conditions of the rings may be corrected in the same manner as for commutators, except for the fact that crocus cloth is used to apply a mirror-like finish following any turning, grinding, or sanding operations.

Pitting can develop because of the electrolytic action on the surface of collector rings caused by current flow. It may occur in only one ring, but will be general over the whole ring area. This condition can be corrected by reversing the polarity of the rings every few days. Reversing the polarity of the d-c field of a 3-phase generator will not affect the phase rotation of the generator.

Field current must not be left on while a machine is secured because it will cause spot pitting and burning of the rings beneath the brushes.

BRUSHES

The brushes used in electric motors and generators are one or more plates of carbon, bearing against a commutator, or collector ring (slip ring) to provide a passage for electrical current for an external circuit. The brushes are held in position by brush holders (fig. 7-11) mounted on studs or brackets attached to the brush-mounting ring, or yoke. The brush holder studs or brackets, and brush-mounting ring comprise the brush rigging. A d-c generator brush holder and brush-rigging assembly are shown in figure 7-12. The brush rigging is insulated from, but attached to, the frame of the machine. Flexible leads (pigtails) are used to connect the brushes to the terminals of the external circuit. An adjustable spring is generally provided to maintain proper pressure of the brush on the commutator in order to effect good commutation.

Any defect in the brush riggings or maladjustment of the spring tension can impair the proper contact between the commutator and the brushes.

Maximum commutation is achieved when the correct grade brushes are set in the holders with allowable clearance and the appropriate spring tension applied to maintain the correct pressure for the particular type brushes.

Correct Brush Type

The correct grade of brush and correct brush adjustment are necessary to avoid commutation trouble. Brushes are manufactured in different grades to meet the requirements of the varied types of service. The properties of resistance, ampere-carrying capacity, coefficient of friction, and hardness of the brush are determined by the maximum allowable speed and load of the machine in which it is used.

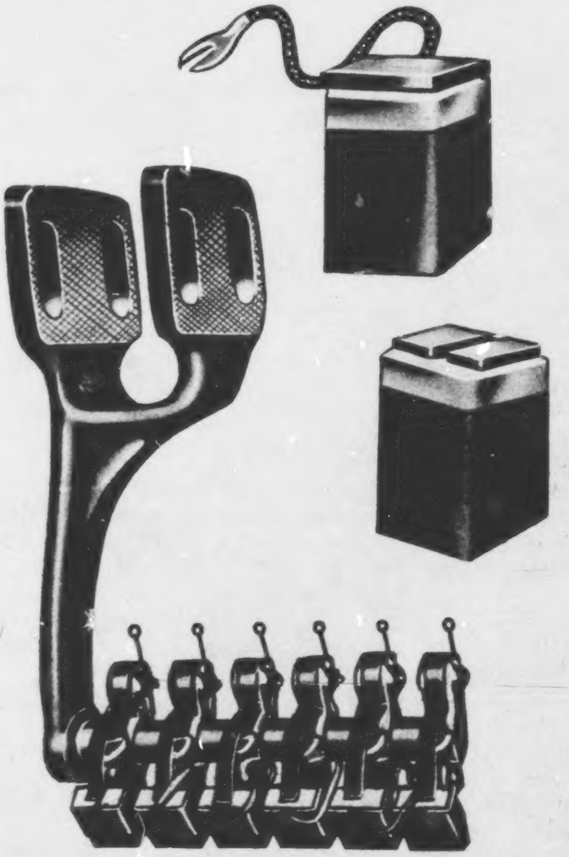


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Figure 7-11.—Brush holder and brushes.

Use the grade of brush indicated in the technical manual. Normally, similarly sized and graded brushes of any manufacturer on the Qualified Products List may be substituted. In certain specialized equipment, however, only one grade of each of two different brush manufacturers is permitted for any machine.

Care

Brushes should move freely in their holders but should not be loose enough to vibrate in the holder.

Brushes should be replaced when they are worn or chipped to such an extent that they will not move properly in their holders; or are worn to within 1/8 inch of the metallic part, or more than 50 percent of the original length of the brush.

Replacement must be preceded by cleaning all dirt and other foreign material from the brush holder.

Where brush springs are of the positive gradient (torsion, tension, or compression) type and are adjustable, they should be adjusted as the brushes wear, in order to keep the brush pressure approximately constant. Springs of the coiled band, constant pressure type and certain springs of the positive gradient type are not adjustable except by changing springs. Brush

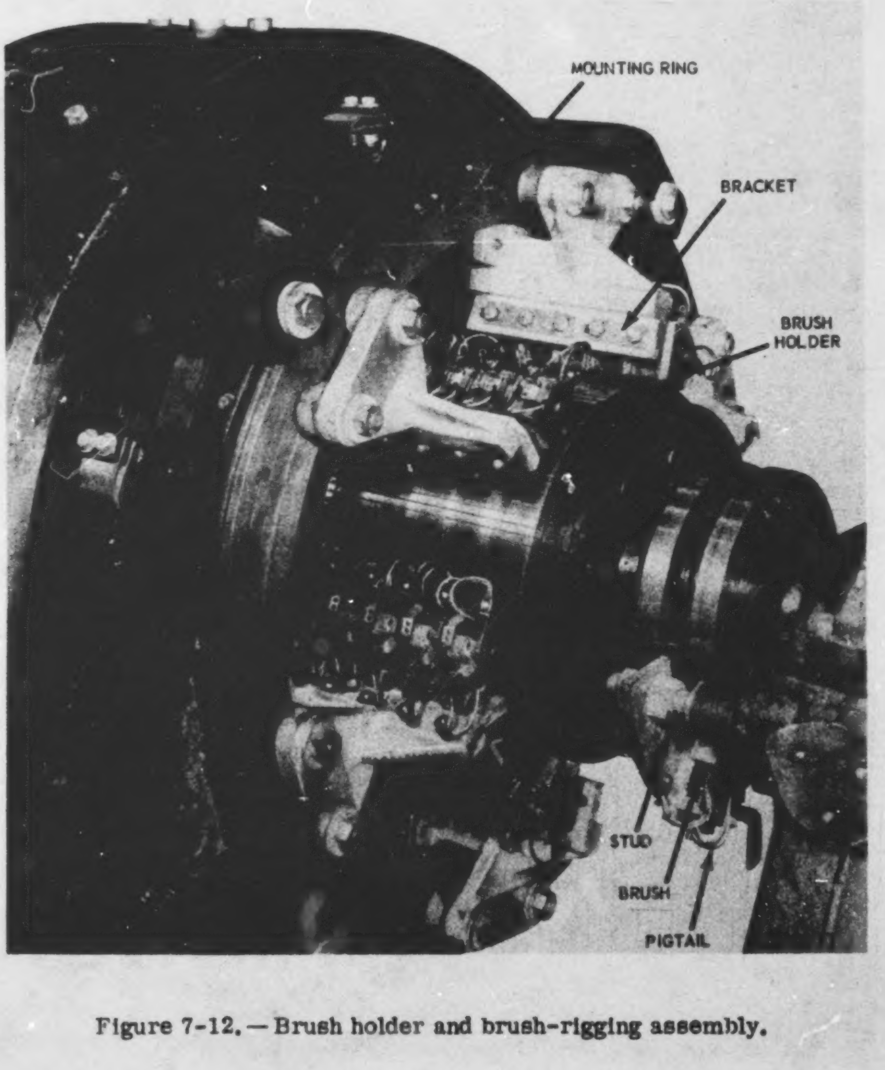

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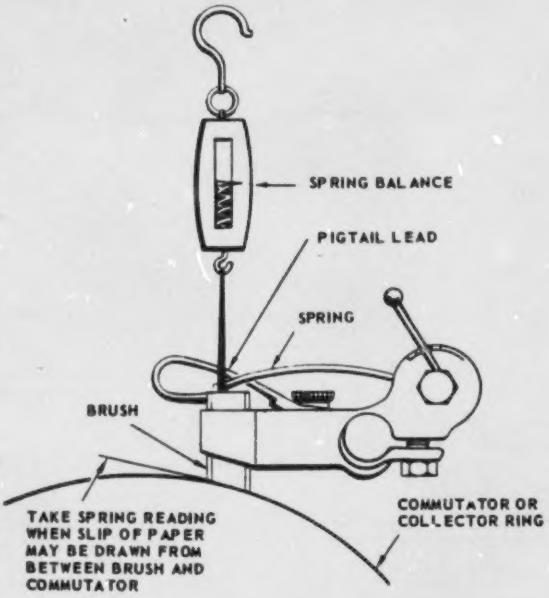
Figure 7-12. — Brush holder and brush-rigging assembly.


SPRING BALANCE
PIGTAIL LEAD
SPRING
BRUSH
TAKE SPRING READING WHEN SLIP OF PAPER MAY BE DRAWN FROM BETWEEN BRUSH AND COMMUTATOR
COMMUTATOR OR COLLECTOR RING

77.72

Figure 7-13.—Measuring brush tension.

pressure should be in accordance with the manufacturer's technical manual. Pressures as low as 1-1/2 pounds per square inch of contact area may be specified for large machines and as high as 8 pounds per square inch of contact area may be specified for small machines. Where technical manuals are not available, a pressure of 2 to 2-1/2 pounds per square inch of contact area is recommended for whole number horsepower and whole number kilowatt machines, and about twice that pressure for fractional horsepower and fractional kilowatt machines.

To measure the pressure of brushes operating in box type brush holders, insert one end of a strip of paper between the brush and commutator; use a small brush tension gage (such as the 0- to 5-pound indicating scale carried in General Stores under Stock No. GS6670-583-0063) to exert a pull on the brush in the direction of the brush holder axis as shown in figure 7-13. Note the reading of the gage when the pull is just sufficient to release the strip of paper so that it can be pulled out from between the brush and commutator without offering resistance. This reading divided by the contact area may be considered to be the unit operating pressure. Taking correction factors into consideration, the actual pressure will be a few percent lower in the case of brushes operating in the leading position and a few percent higher in the case of brushes operating in the trailing position.

All brush holders should be the same distance from the commutator, not more than one-eighth inch, nor less than one-sixteenth inch.

The toes of all brushes on each brush stud should line up with each other and with the edge of one commutator segment.

The brushes should be evenly spaced around the commutator. To check brush spacing, wrap a strip of paper around the commutator and mark the paper where the paper laps. Remove the paper from the commutator, cut at the lap, and fold or mark the paper into as many equal parts as there are brush studs. Replace the paper on the commutator and adjust the brush holders so that the toes of the brushes are at the creases or marks.

Seating

Accurate seating of the brushes must be assured where their surfaces contact the commutator. Sandpaper and a brush seater are the best tools to accomplish a true seat.

All power must be disconnected from the machine, and every precaution must be taken to ensure that the machine will not be inadvertently started before and whenever using sandpaper to seat the brushes. The brushes to be fitted are lifted, and a strip of fine sandpaper (No. 1) approximately the width of the commutator, is inserted (sand side up) between the brushes and the commutator. With the sandpaper held tightly against the commutator surface to conform with the curvature and the brushes held down by normal spring pressure, the sandpaper is pulled in the direction of normal rotation of the machine (fig. 7-14). When returning the sandpaper for another pull, the brushes must be lifted. This operation is repeated until the seat of the brush is accurate. Always finish with a fine grade of sandpaper, No. 0. A vacuum is required for removing dust while sanding. After sanding, the commutator and windings must be thoroughly cleaned to remove all carbon dust.

The brush seater is compounded of a mildly abrasive material loosely bonded, and is formed in the shape of a stick about 5 inches in length.

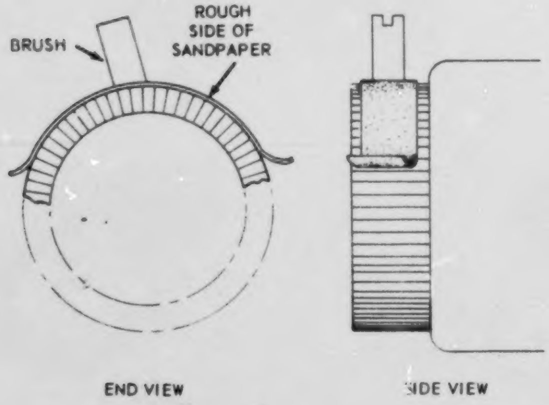


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Figure 7-14. — Method of sanding brushes.

The brush seater is applied to the commutator while the machine is running, and every precaution should be taken to prevent injury to the person applying it. The brush seater is touched lightly, for a second or two, exactly at the heel of each brush (fig. 7-15). If placed even one-fourth inch away from the heel, only a small part of the abrasive will pass under the brush. Pressure may be applied to the brush by setting the brush spring tension at maximum or by pressing a stick of insulating material against the brush. The dust is removed during the operation, and the machine is thoroughly cleaned afterwards in the same manner as for sanding brushes.

Brushes should be staggered as shown in figure 7-16 to prevent grooving of the commutator.

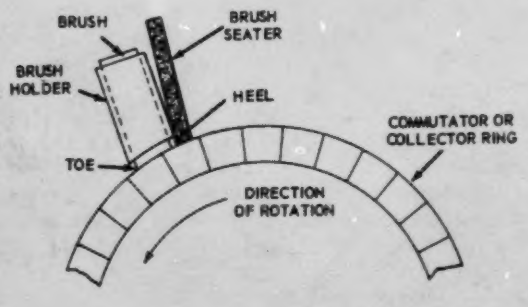

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Figure 7-15. — Using the brush seater.

For machines having a number of poles equal to two times an odd number, it will obviously not be possible to stagger all the brushes in accordance with the correct method shown. Stagger all but the odd pair of positive and negative brushes in accordance with the correct method, and the odd pair as shown in view B of figure 7-16.

Setting on Neutral

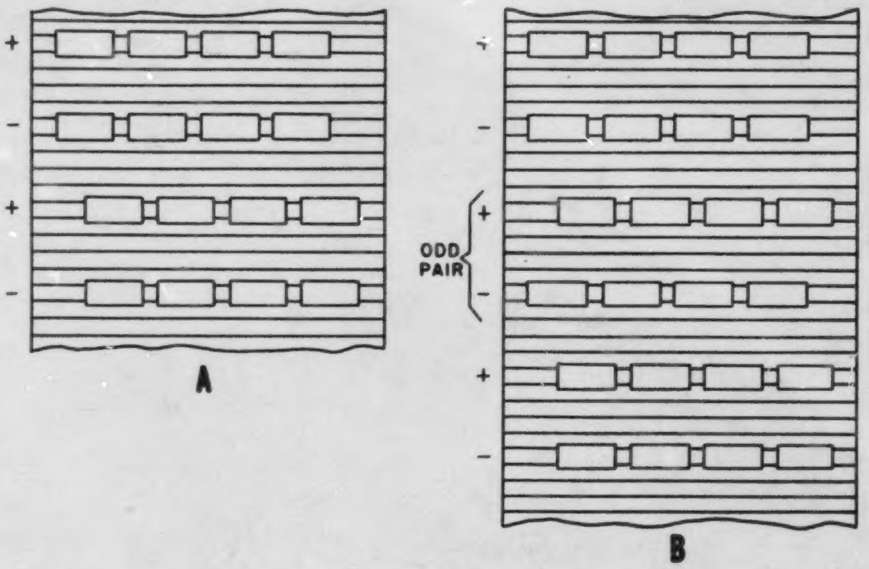
When a machine is running without load and with only the main-pole field windings excited, the point on the commutator at which minimum voltage is induced between adjacent commutator bars is the no-load neutral point. This is the best operating position of the brushes on most commutating-pole machines. Usually, the brush studs are doweled in the proper position, and the correct setting is indicated on a stationary part of the machine by a chisel mark or an arrow. In some cases, commutation may be improved by shifting the brushes slightly from the marked position.

The correct neutral position can be found by the use of:

1. The mechanical method.
2. The reversed rotation method.
3. The inductive kick method.

The mechanical method is an approximate method. Turn the armature until the two coil sides of the SAME armature coil are equidistant from the centerline of one MAIN field pole. The commutator bars to which the coil is connected give the position of the mechanical neutral.

Use of the reversed rotation method is possible only where it is practicable to run a machine in either direction of rotation, with rated load applied. This method differs for motors and generators. For motors, the speed of the motor is, at first, accurately measured when the field current becomes constant under full load at line voltage with the motor running in the normal direction. Then, the rotation of the motor is reversed, full load is applied, and the speed is again measured. When the brushes are shifted so that the speed of the motor is the same in both directions, the brushes will be in the neutral position. Generators are run at the same field strength and same speed in both directions,



77.71

Figure 7-16.—Correct method of staggering brushes.

and the brushes are shifted until the full-load terminal voltage is the same for both directions of rotation. To ensure accuracy, a reliable tachometer must be used to measure the speed of the machines for this method.

The kick method should be used only when the other methods are inadequate and the conditions are such as to warrant the risks involved, and then only when sufficient resistance is connected in series with the field coils to reduce the field current to approximately 10 percent of normal value.

BALL BEARINGS

Rolling, antifriction bearings are of two types: ball and roller bearings. Basically, all rolling bearings consist of two hardened steel rings, hardened steel rollers or balls, and separators. The annular, ring-shaped, ball bearing is the type of rolling bearing used most extensively in the construction of electric motors and generators used in the Navy. This bearing is further divided into three types dependent upon the load it is designed to bear—(1) radial, (2) angular contact, and (3) thrust. Examples of these three bearings are shown in figure 7-17.

The rotating element of an electric motor or generator may subject a ball bearing to any one or a combination of three loads—radial, thrust, and angular. Radial loads are the result of forces applied to the bearing perpendicular to the shaft; thrust loads are the result of forces applied to the bearing parallel to the shaft; and angular loads are the result of a combination of radial and thrust loads. Because the load carried by the bearings in electric motors and generators is almost entirely due to the weight of the rotating element, it is apparent that the method

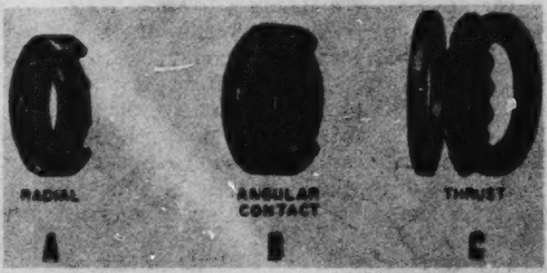


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Figure 7-17.—Representative types of ball bearings.

of mounting the unit is a major factor in determining the type of bearing employed in its construction. In a vertically mounted unit, the thrust bearing would be used; while the radial bearing is common to most horizontal units.

The preventive maintenance of ball bearings requires periodic checks of bearing wear, and adequate lubrication.

Wear

Measuring air gaps to determine bearing wear is not necessary on machines equipped with ball bearings because the construction of the machine is such as to ensure bearing alignment. Ball bearing wear of sufficient magnitude as to be readily detected by air-gap measurements would be more than enough to cause unsatisfactory operation of the machine.

The easiest way of determining the extent of wear in these bearings is to periodically feel the bearing housing while the machine is running to detect any signs of overheating or excessive vibration, and to listen to the bearing for the presence of unusual noise. The indications thus obtained are comparative, and caution must be exercised in their analysis.

When testing for overheating, the normal running temperature of the bearing must be known before the test can be reliable. Rapid heating of a bearing is indicative of danger. While a bearing temperature uncomfortable to the hand may be a sign of dangerous overheating, it is not always so. The bearing may be all right if it has taken an hour or more to reach that temperature; whereas, serious trouble can be expected if that same temperature is reached within the first 10 or 15 minutes of operation.

The test for excessive vibration relies to a great extent on the experience of the person conducting the test. He should be thoroughly familiar with the normal vibration of the machine in order to be able to correctly detect, identify, and interpret any unusual vibrations. Vibration, like heat and sound, is easily telegraphed, and thorough search is generally required to locate its source and to determine its cause.

Ball bearings are inherently more noisy in normal operation than sleeve bearings, discussed later, and this fact must be borne in mind by personnel testing for the presence of abnormal noise in the bearing. A good method for sound testing is to place one end of a screwdriver or steel rod against the bearing housing and the other end against the ear. If a loud, irregular grinding, clicking, or scraping noise is heard, trouble is indicated. As before, the degree of reliance on the results of this test depends on the experience of the person conducting the test.

Checking a motor or generator shaft can give a good indication of the amount of wear, as shown in figure 7-18. View A illustrates that if the motor shaft has vertical movement, worn bearings are indicated. View B illustrates motor or generator end-play movement and is corrected with bearing shims.

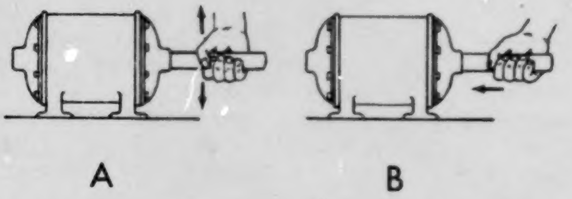
Bearing Installation

Representative techniques for bearing removal are shown in figures 7-3 and 7-4. Four acceptable methods for installing bearings exist. These are called the arbor press, infrared, oven, and hot-oil methods. The technique you use will depend upon the equipment available.

ARBOR PRESS METHOD.—If available and adaptable, and proper precautions are taken, an arbor press can be used. Place a pair of flat steel blocks under the inner ring or both rings of the bearing. Never place blocks under the outer ring only. Then line up the shaft vertically above the bearing, and place a soft pad between shaft and press ram. After making sure the shaft is started straight in the bearing, press the shaft into the bearing until the bearing is flush against the shaft or housing shoulder.

INFRARED METHOD.—A bearing can be heated using an infrared oven to expand the inner ring for assembly. The bearing should not be heated above 200° F. This method ensures uniform heating all around the bearing.

OVEN METHOD.—Alternatively, bearings can be heated to expand the inner ring for assembly in a temperature-controlled furnace at a temperature not to exceed 200° F. The bearing should not be left in the furnace beyond the time necessary to expand the inner race the desired amount, since heating for an excessive period of time would give rise to the possibility of deterioration of the grease with which the bearing is prelubricated.



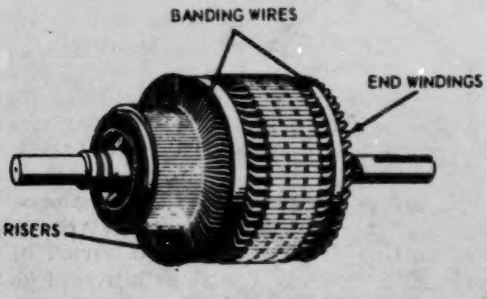
73.300
Figure 7-18.—Checking motor or generator shafts. (A) Vertical movement; (B) End-play movement.

HOT-OIL METHOD.—A fourth method used in installing bearings is the hot-oil method, which consists of heating the bearing in oil at 200° F until expanded and then slipping it on the shaft. This method is not desirable and should not be used unless absolutely necessary.

Note: When pressing a bearing onto a shaft, pressure must be applied to the inner ring, but when pressing a bearing into a housing, pressure must be applied to the outer ring.

Before the final assembly has been completed, the entire unit should be thoroughly checked for alignment.

The bearing should be packed with the proper lubricant and the cleaned bearing housing should be half filled with the same lubricant. The housing must be properly assembled and care must be exercised to prevent omission of bearing parts, lubricant seals, grease pipes, plugs, and fittings. These parts must be securely assembled to complete the housing closure and protect against the entrance of foreign materials. Both should be tightened evenly. Any "V" grooves in the housing lip should be filled with grease which will act as an additional seal to protect against entrance of dirt.



5.143
Figure 7-19.—A d-c armature.

ARMATURES

Preventive maintenance of an armature consists of periodic inspections and tests to determine its condition, and proper cleaning practices to preserve the insulation.

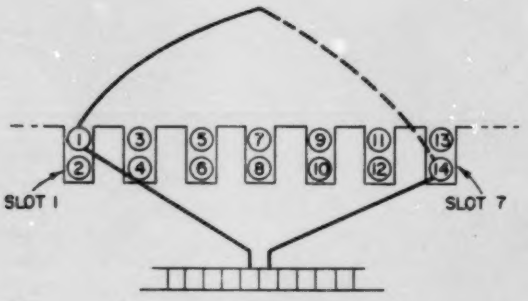
Frequent checks must be made of the condition of the banding wire that holds down the windings of the d-c armature to see that the wires are tight, undamaged, and have not shifted (fig. 7-19). At the same time, the clips securing the wires should be checked to see if solder has loosened. When repairs are required, banding-wire size, material, and the method of original assembly should be duplicated as far as possible. Only pure tin must be used for soldering banding wire.

Periodically, all end windings should be inspected and cleaned (fig. 7-19). Allow sufficient clearance between the end windings and end brackets or any air deflecting shields to prevent chafing or other damage. In cases where shop overhaul is not feasible, air-drying varnish may be applied to the windings by brush after they have been cleaned and dried.

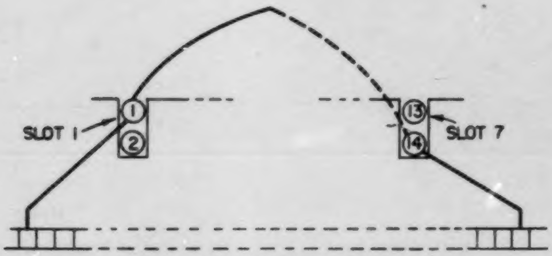
Risers must be inspected periodically to determine the condition of the solder that secures the windings to the segments (fig. 7-19). All dirt and lint should be removed by thorough cleaning to ensure that cooling passages will not be clogged. It may be necessary in the case of generators to do this each time the machine is secured. Cleaning is easier when performed while the machine is warm.

Winding Identification

It is important for you to be able to identify armature windings because the type must be determined in order to understand the trouble indications and to make the necessary repairs. Your complete understanding of LAP, WAVE, PROGRESSIVE, and RETROGRESSIVE windings is vital. Furthermore, your understanding and application of terms such as PITCH, COIL



A SINGLE-TURN LAP COIL



B SINGLE-TURN WAVE COIL

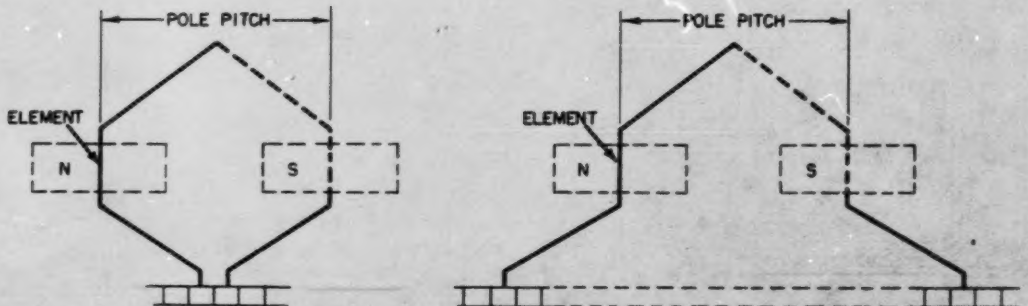
111.1

Figure 7-20.—Classification of armature windings.

PITCH, and SIMPLEX, DUPLEX and TRIPLEX connections will enable you to perform your jobs quickly and efficiently.

LAP AND WAVE WINDINGS.—Armature windings, irrespective of how the elements are placed on the armature core, are generally classified as LAP or WAVE windings. The classification designates the method of connecting the ends of the elements, or coils, to the commutator (fig. 7-20). If the ends of the coil are connected to adjacent commutator segments, or to segments that are close together, the coil is designated as a lap-connected coil, and the winding is a lap winding (view A of the figure). On the other hand, if the ends of a coil are connected to commutator segments approximately two pole pitches apart, the coil is designated as a wave-connected coil, and the winding is a wave winding. (See fig. 7-20, view B and fig. 7-21.)

PITCH.—Both lap and wave windings are placed on the armature core so that the two sides of an element occupy slots that are influenced by adjacent poles of opposite polarity, and the emf's generated in the two sides add together. In other words, if the left side of a coil momentarily occupies a position under the center of a north pole, the right side of the same coil will occupy a position under approximately the center of an adjacent south pole. The distance between the centers of two adjacent poles is the pole pitch. The span of one coil should be equal or nearly equal to one pole



A LAP COIL

B WAVE COIL

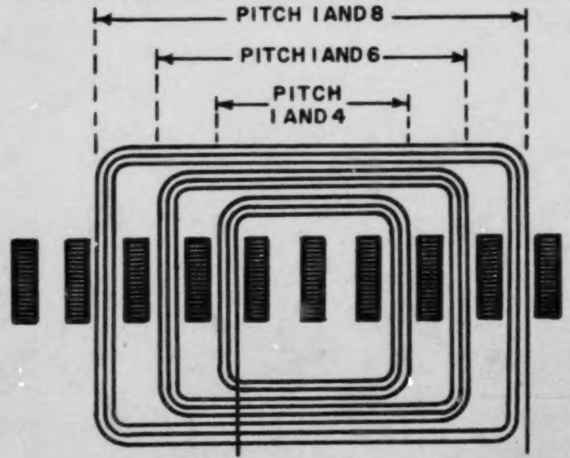
111.2

Figure 7-21.—Full-pitch coils.

pitch. If a coil spans exactly one pole pitch, the winding is FULL PITCH (fig. 7-21), and if a coil spans less than one pole pitch, the winding is FRACTIONAL PITCH. COIL PITCH is recorded and identified by the number of slots spanned by the coil in the armature (fig. 7-22).

NUMBERING.—Usually d-c armature windings are two-layer windings in which each slot contains two coil sides of a single-coil type of winding (fig. 7-20). Thus one side of the winding element is placed in the top of a slot, and the other side is placed in the bottom of another slot. It is immaterial which side of the element is placed in the top or bottom of the slot. In practice (observing the armature from the commutator end) the right side of the coil is usually placed in the bottom of one slot and the left side is placed in the top of another slot. The coil sides are arbitrarily numbered so that all TOP coil sides have odd numbers and all BOTTOM coil sides have even numbers (fig. 7-20). This system helps to place the coils properly on the armature.

PROGRESSIVE AND RETROGRESSIVE WINDINGS.—Lap and wave windings can be progressive or retrogressive, as illustrated in figure 7-23. A PROGRESSIVE WINDING (view A) progresses in a clockwise direction around the armature when traced through the winding from the commutator end. In other words, the winding progresses clockwise from segment (bar) through the coil to segment.



73.132
Figure 7-22.—Progressive and retrogressive windings.

Progressive wave winding and retrogressive lap windings are very seldom encountered because of the inherent undesirable features, such as the end connections of coil groups crossing over each other, added weight, and longer leads. Therefore, with few exceptions lap windings are progressive and wave windings are retrogressive.

A RETROGRESSIVE WINDING (view B of fig. 7-23) progresses in a counterclockwise direction around the commutator end.

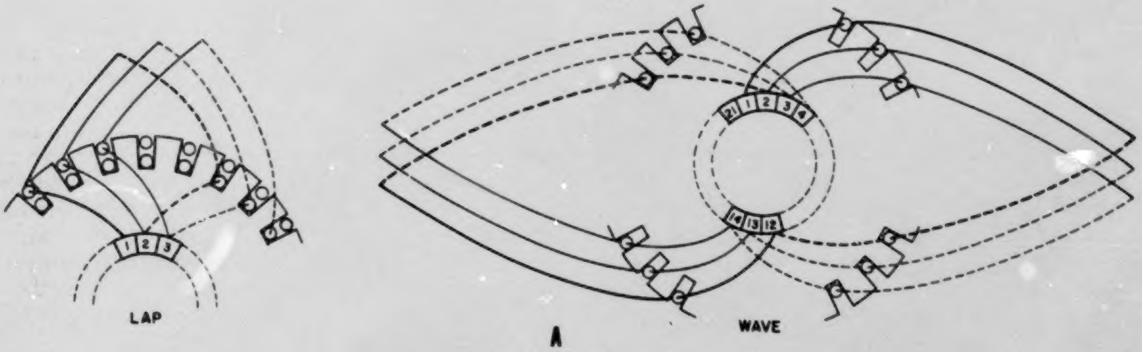
MULTIPLEX WINDINGS.—Windings may also be classified and connected in SIMPLEX, DUPLEX, or TRIPLEX. A simplex lap winding is one in which the beginning and ending leads of a lap wound coil are connected to adjacent commutator bars. Duplex lap winding leads are connected two bars apart, and triplex lap winding leads are connected three bars apart.

Progressive and retrogressive simplex lap windings are shown in figure 7-24. As you can see, the progressive lap winding is one in which the current flowing in a coil terminates in the commutator bar clockwise adjacent to the starting bar as you view the armature from the commutator end. A retrogressive simplex lap winding is one in which the current in the coil terminates in the bar counterclockwise adjacent to the starting bar.

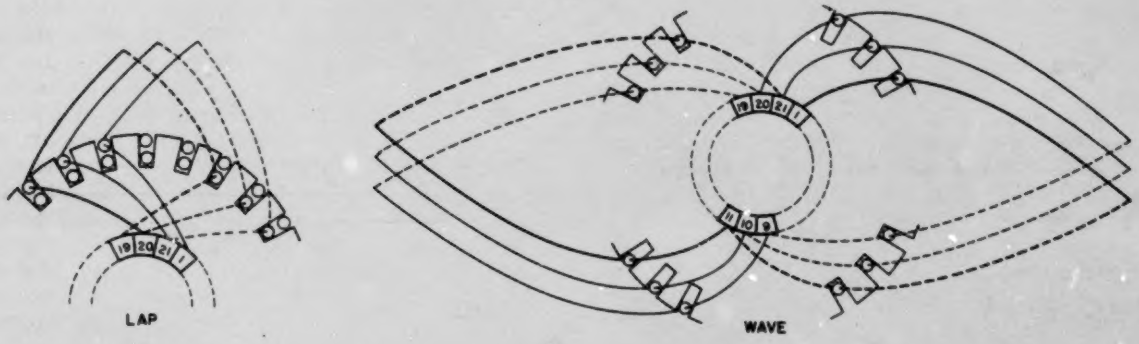
Simplex progressive and retrogressive wave windings are shown in figure 7-25. Compare these with the lap windings shown in figure 7-24. When you have to identify armature windings, you might think it will be complicated. Use of an organized test procedure will enable you to distinguish the types.

Test Procedures

There are many armature testing techniques. One method is to use a low-reading ohmmeter to indicate variations in the resistance readings as the test probes are shifted around on the commutator. If a low-reading ohmmeter is not available, a milliammeter connected in series


1
2
3
LAP
21
1
2
3
4
14
13
12
WAVE

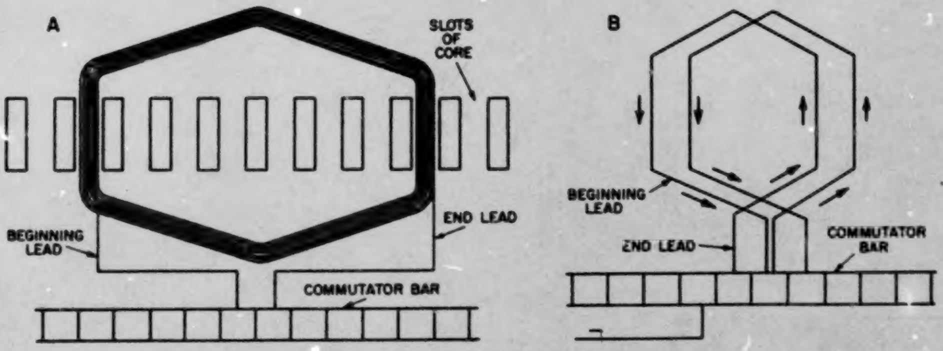
A
PROGRESSIVE


19
20
21
1
LAP
19
20
21
1
11
10
9
WAVE

B
RETROGRESSIVE

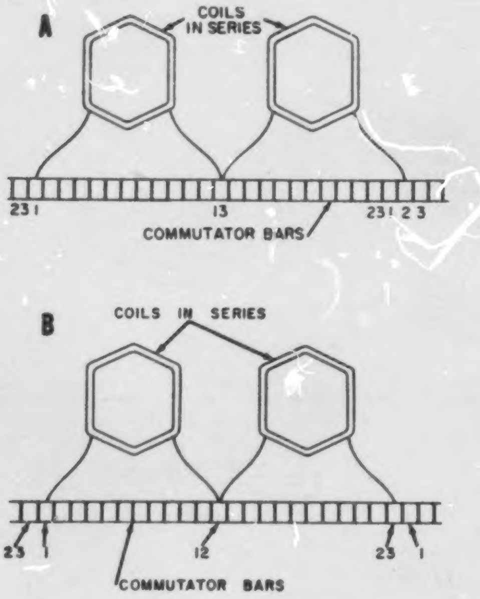
111.3

Figure 7-23.—Meaning of coil pitch in armature winding.


A
SLOTS OF CORE
BEGINNING LEAD
END LEAD
COMMUTATOR BAR
B
BEGINNING LEAD
END LEAD
COMMUTATOR BAR

73.230

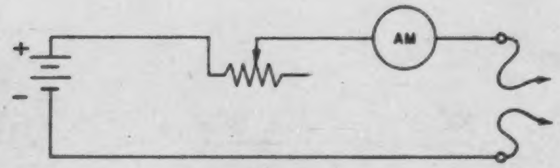
Figure 7-24.—Simplex lap windings. (A) Progressive; (B) Retrogressive.



73.231
Figure 7-25.—Four-pole simplex wave windings. (A) Progressive; (B) Retrogressive.

with a rheostat and a 6-volt battery can be used (figure 7-26).

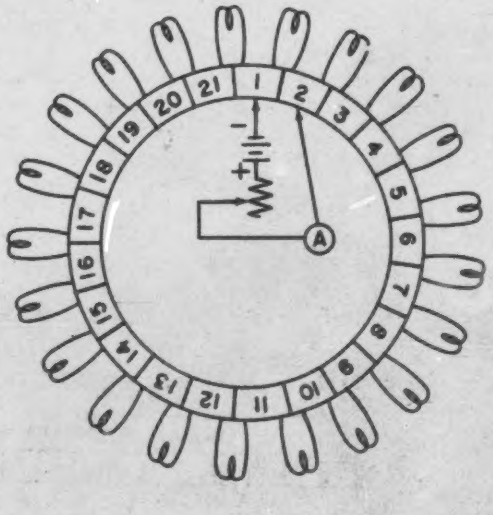
SIMPLEX LAP.—A schematic diagram of a simplex lap winding is illustrated in figure 7-27. With the test probes placed on adjacent segments, the ammeter will indicate a maximum because the resistance of only one coil shunts the remainder of the winding, and the resistance added to the test circuit is at minimum. Move one test probe to the next segment, and the ammeter reading decreases because the resistance between the probes has increased. With one probe stationary and the other probe contacting each segment in succession around the commutator, the armature indications will decrease steadily until the test probes are directly opposite each other, and then start increasing steadily as the other half of the winding is tested. These indications are obtained because of the method of connecting the coils to the commutator, which is determined by the type of winding. A simplex lap winding is the only winding that gives these indications.



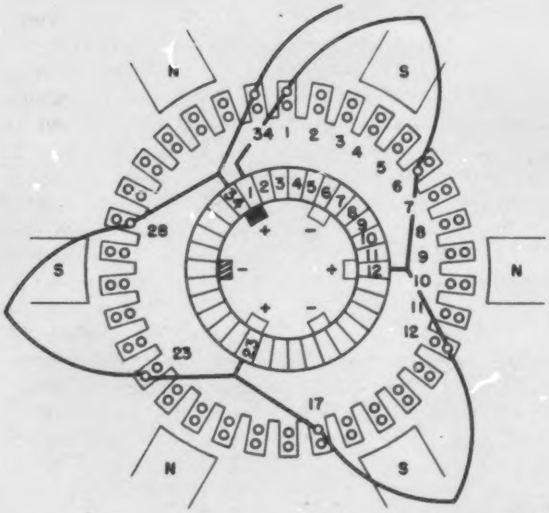
111.6
Figure 7-26.—Test circuit for measuring armature.

SIMPLEX WAVE.—An important rule to remember for all wave windings is that the ends of each coil are connected to commutator segments that are approximately two pole pitches apart. Using the test procedure described previously, the maximum ammeter reading is indicated when the test probes are connected across that portion of the winding in which one coil shunts the remaining portion of the winding. Hence, in all wave windings the maximum reading will be indicated when the probes are placed on commutator segments that are approximately two pole pitches apart. The minimum ammeter reading will occur when the probes are placed on segments approximately one pole pitch apart.

With one probe stationary on segment 1 (fig. 7-28) and the other probe moved around the



111.7
Figure 7-27.—Schematic of simplex lap winding.



111.12

Figure 7-28.—Portion of 6-pole, simplex wave winding.

commutator from segment to segment (2, 3, 4, and so forth), the ammeter readings steadily decrease until the probes are approximately one pole pitch apart, and then the readings steadily increase until the probes are approximately two pole pitches apart.

If the probe is circled around the remainder of the commutator, the readings will decrease and then increase once for each pair of poles. In the identification of a 6-pole, simplex wave winding there will be three successive decreases and increases in the meter readings as the commutator is circled once. Similarly, in a 4-pole simplex wave winding there will be two successive decreases and increases in the meter readings. Thus, a simplex wave winding can be readily distinguished from a simplex lap winding by measuring the resistances of the armature coils.

Trouble Indications

Some armature troubles may be detected while making inspections of running machines. Heat and the odor of burning insulation may indicate a short-circuited armature coil. In a coil that has some turns shorted, the resistance of one turn of the coil will be very low, and the voltage generated in that turn will cause a high-current flow, resulting in excessive heating, which will cause the insulation to burn. If the armature is readily accessible, the short-circuited coil can be detected immediately after stopping the machine because the shorted coil will be much hotter than the others. In idle machines, a short-circuited coil may be identified by the presence of charred insulation.

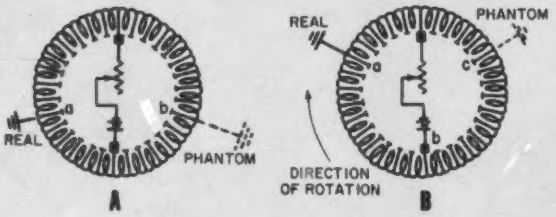
An open armature coil in a running machine is indicated by a bright spark, which appears to pass completely around the commutator. When the segment to which the coil is connected passes under the brushes, the brushes momentarily complete the circuit; when the segment leaves the brushes, the circuit is broken, causing a spark to jump the gap. Eventually, it will definitely locate itself by scarring the commutator segment to which one end of the open coil is connected.

When a ground occurs in an armature coil of a running machine, it will cause voltage fluctuation as the grounded coil segment passes from brush to brush during rotation of the armature. Two grounded coils result in the same effect as a short circuit across a group of coils. Overheating will occur in all of the coils in the group and burn out the winding. Grounded coils in idle machines can be detected by measuring insulation resistance. A megger, or similar insulation measuring device, can be connected to the commutator and to the shaft or frame of the machine in order to properly measure the resistance of the insulation of the coils.

Locating Troubles

Usually d-c armature troubles are confined to one coil or group of coils, and if not readily apparent, the segments to which they are connected can be located by a bar-to-bar test or use of a growler.

BAR-TO-BAR TEST.—A low voltage, d-c source, such as a storage battery, lighting circuit, or welding set, is required for this test. The machine must be disconnected from its normal power supply before the test is made and all except one pair of brushes lifted from the commutator. The voltage is applied across the

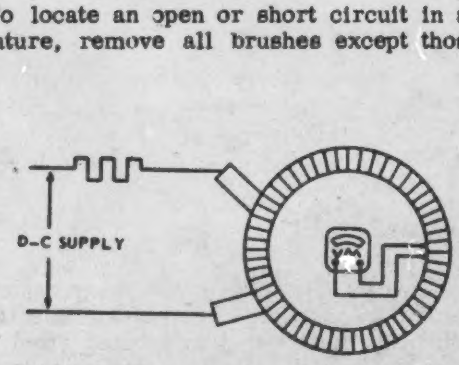


77.75
Figure 7-29.—Real and phantom grounds in bar-to-bar test.

+ and - brush through a resistance, lamp, lamp bank, or rheostat. A low-reading voltmeter or millivoltmeter is necessary for taking measurements.

To locate a ground in a d-c armature coil, one lead of the voltmeter is connected to the shaft, and, with the armature in a fixed position, the other lead is touched to each commutator bar in turn. If there is a ground, two or more bars will indicate practically zero readings. Some of these will be real and others will be phantom grounds (fig. 7-29, view A). All such bars should be marked with chalk. The armature is then rotated a few degrees and tested again. The real grounds will remain in the same bars while the phantom ones will shift to other bars. For example, in view B of figure 7-29, the phantom ground has shifted from bar b to bar c, while the real ground has remained in bar a. The ground will be in a coil connected to the bar, showing a real ground with the lowest voltage reading.

To locate an open or short circuit in a d-c armature, remove all brushes except those of one positive brush holder and an adjacent negative brush holder. Connect the low-voltage potential to these brushes and adjust the current, if need be, so that the readings obtained with the millivoltmeter will be roughly one-third to one-half full scale. The current must not exceed one-fourth that normally carried by one set of brushes. The voltage drop between two adjacent commutator bars is measured with a millivoltmeter. The armature is held in a fixed position, and the meter leads are moved from one pair of adjacent bars to the next until a test has been made of all the pairs of bars included between the brushes (fig. 7-30). The armature is then turned to bring different bars between the brushes, and these bars are tested. This is repeated as necessary to test all around the commutator. In a simplex winding, an open coil is located where the meter reading is a maximum, and a shorted coil where the reading is a minimum.



77.76
Figure 7-30.—Testing for an open coil.

For most armatures the windings will be free from fault if all the voltage readings are a small fraction of the voltage between the brushes and are equal within the limits of measurement. However, in some cases, a duplex winding may be encountered. This type of winding is indicated when the readings are only a small fraction of the voltage between the brushes and follow each other in a regularly repeating pattern such as O, R, O,R,O,R, and so on, where R is a reading different from zero. When this happens, a further test must be made by measuring the voltage drop between alternate bars—1 and 3, 2 and 4, 3 and 5, 4 and 6, and so on. If these readings are equal within the limits of measurement, the winding will be free from faults.

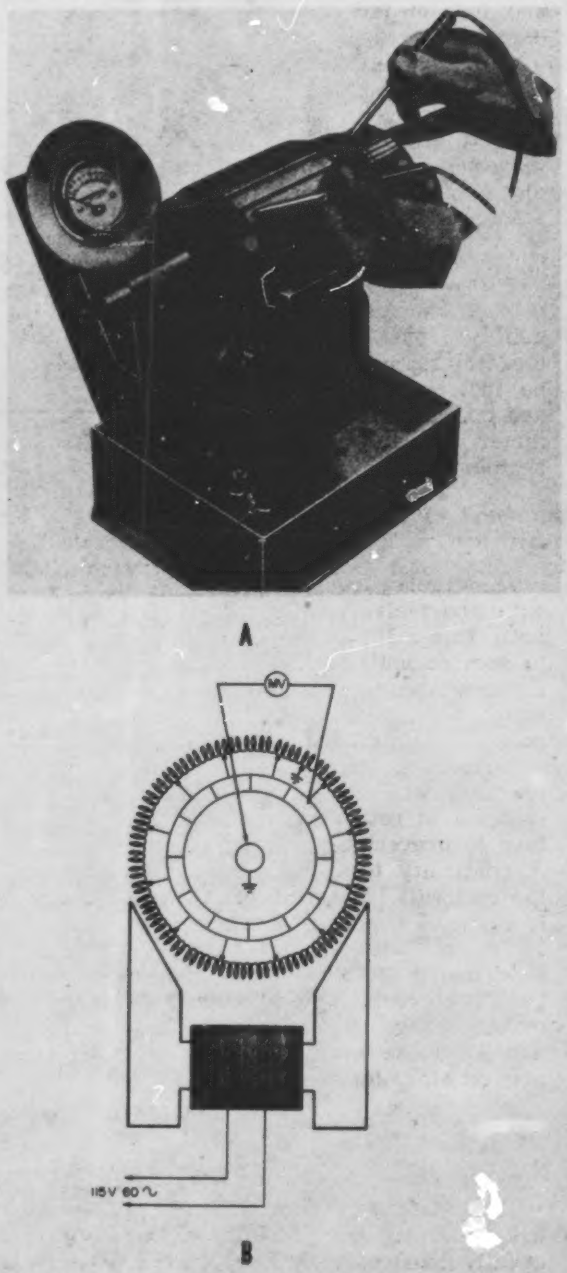
When an open circuit is present, the voltmeter reading across one pair of adjacent bars will be approximately equal to the voltage between the brushes, and zero readings will be obtained on several pairs of bars on each side of the pair with the high reading. The open-circuited coil will be connected to one or both of the bars in the pair with the high reading. Should the voltmeter readings taken between adjacent pairs of bars increase or decrease in magnitude and be alternately plus and minus, a duplex winding is indicated. A further test by measuring the voltage drop between alternate bars is then necessary to locate the open circuit. When a reading approximating the voltage between the brushes is thus obtained, the open-circuited coil will be connected to one or both of the bars in the pair with the high reading.

When a short circuit is present, the interpretation of the indication given by readings between adjacent bars or between alternate bars (duplex windings) depends upon whether the armature has a lap or a wave winding. In an armature having a lap winding, a voltmeter reading considerably lower than the others will indicate a short-circuited coil is connected between the pair of bars that shows the low reading. A short-circuited coil in an armature with a wave winding will cause low readings to be obtained on as many pairs of bars as there are pairs of poles, and the short circuit will be in a coil connected to bars in these pairs.

The best method for locating the ends of a faulty coil in a wave-wound armature is to separate the coil from the rest of the winding in the following manner. In a 6-pole machine, a short-circuited coil in a wave-wound armature would be indicated at three positions during the test. These positions should be marked with chalk. When the riser connections on these segments are lifted, six coils will be isolated from each other and the rest of the winding. The shorted coil is located by comparing the resistances of the six coils, and it will have less resistance than the others.

GROWLER TESTS.—A growler (fig. 7-31) can be used to detect and locate grounds, opens and shorts in small armatures. The device consists of a coil of wire wound around an H-shaped, laminated iron core. The laminations on top are cut out to hold the armature under test between the two poles of the growler. When an alternating current is applied to the coil, an emf will be induced in the armature coils by transformer action.

To test an armature for grounds with the growler, place the armature on the poles of the growler and energize the coil from a 115-volt source. Connect one lead of an a-c millivoltmeter to the armature shaft and use the other lead as a probe, contacting each commutator segment one at a time in sequence (fig. 7-31, view A). If there are no grounds in the winding, no reading will be indicated on the meter because the commutator is insulated from the shaft. If there is a ground in the winding, a reading will be indicated on the meter for all good coils (view B of fig. 7-31). No reading on the meter indicates that the grounded coil is connected to this segment.



2.92

Figure 7-31. —Growler.

To test an armature for shorted coils with the growler, place the armature on the growler and turn on the current. Hold a hacksaw blade directly over, and along the length of, the top slot. If the coil in this slot is shorted, the blade will vibrate rapidly and cause a growling noise. If the blade does not vibrate, it is an indication that no short exists in the coil. Test each slot in sequence by turning the armature so that the slot to be tested is on top.

To test a simplex lap or wave armature for opens with the growler, set up the armature on the growler in the usual manner. Test the top two adjacent segments with an a-c millivoltmeter. Turn the armature and continue testing the two top adjacent segments. A reading will be indicated on the meter of all segments that are connected to good coils. No reading on the meter indicates an open coil between the two segments.

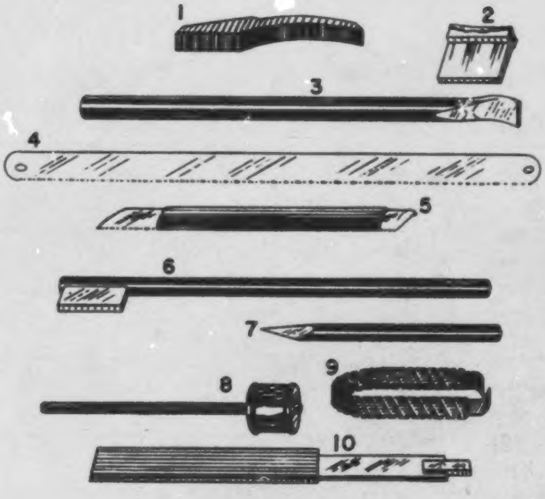
Emergency Repairs

Emergency repairs can be effected by cutting out a short-circuited or open-circuited armature coil. This will permit restoration of the machine to service until permanent repairs can be made. However, permanent repairs should be made as soon as possible. The coil is cut out by disconnecting both ends of the coil and installing a jumper between the two risers from which the coil was disconnected. The coil itself is then cut at both the front and rear of the armature to prevent overheating of the damaged coil. A continuity test from one end to the back of the coil will locate the turns of the faulty coil. If a pin or needle is used to puncture the insulation for this test, insulating varnish can be used to fill the tiny hole in the event the wrong coil is pierced. All conducting surfaces exposed by the change in connections should be insulated and all loose ends should be tied securely to prevent vibration.

Handtools

The handtools used in rewinding armatures are relatively few and simple. In fact, they are usually handmade by Construction Electricians engaged in this work. Figure 7-32 shows the following tools:

1. Fiber horn for shaping the coil ends after the coils are placed in the slots.



1. Fiber horn
2. Steel slot drift or tamping tool
3. Lead lifter
4. Hacksaw blades
5. Saw
6. Wedge driver
7. Lead drift
8. Rotation indicator
9. Wire scraper
10. Wedge inserter

111.17
Figure 7-32.—Armature rewinding handtools.

2. Steel slot drift, or tamping tool, for driving the coils to the bottom of partly closed slots.

3. Lead lifter for lifting the coil leads from the commutator risers.

4. Hacksaw blades for removing the fiber wedges that hold the coils in the slots.

5. Saw for undercutting the commutator mica between the segments.

6. Wedge driver for driving the fiber wedges out of the slots.

7. Lead drift for cutting off the leads at the risers.

8. Rotation indicator as an aid to determine the proper connections of the windings.

9. Wire scraper for removing the insulation from the ends of the coil leads.

10. Wedge inserter for driving the wedges into partly closed slots.

Stripping

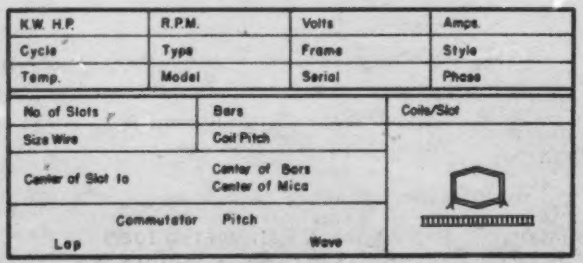
Before stripping an armature, record all available winding data on an armature data card, as shown in figure 7-33, for use in rewinding and for future reference.

After recording the initial winding data, perform a bar-to-bar test to determine if the winding is lap or wave and record this information on the armature data card and proceed to disconnect and remove the coils.

During this process, accumulate the winding data that was impossible to obtain before stripping the armature. Remove the banding wires by filing them in two places. If banding wires are not used, remove the wedges in the slots. A simple means of removing the wedges is to place a hacksaw blade, with the teeth down, on the wedge. Tap the top of the blade to set the teeth in the wedge and then drive out the wedge by tapping the end of the blade.

Next, unsolder the coil leads from the commutator and raise the top sides of the coils the distance of a coil throw (distance between the two halves of a coil). The bottom side of a coil is now accessible, and the other coils can be removed one after the other. Exercise care to preserve at least one of the coils in its original shape for use as a guide in forming in the new coils. Next, record the wire size, number of turns in a coil, and type of insulation on the coils and in the slots.

To raise the coils without damaging the insulation, use a small block of wood as a fulcrum resting on the armature core and a steel bar or piece of wood as a lever.



K.W. H.P.	R.P.M.	Volts	Amps.
Cycle	Type	Frame	Style
Temp.	Model	Serial	Phase

No. of Slots	Bars	Coils/Slot
Size Wire	Coil Pitch	
Center of Slot to	Center of Bars Center of Mica	
Commutator Pitch Lap	Wave	

111.18

Figure 7-33. — A d-c armature data card.

After the coil is partly raised, drive a tapered fiber wedge between the top and bottom coils within the slot to finish raising the top coil from the slot. After stripping the armature, remove all dirt, grease, rust, and scale by sand blasting. File each slot to remove any burrs or slivers and clean the core thoroughly with compressed air. Immerse the cleaned armature core in a varnish and bake in accordance with the steps in table 7-1, using a dilute varnish (20 percent solution) of the same type of varnish to be used after winding.

This treatment prevents the formation of oxides and forms a base for the adherence of the final varnish treatment.

Winding Armature Coils

Formed coils are wound on a coil-winding machine and pulled into the desired shape on the forming machine. The shape of the coil is determined by the old coil. The two wires forming the leads are taped with cotton or reinforced mica tape. The binder insulation, consisting of cotton or glass tape, is applied to the entire coil surface.

The coil is now sprayed with a clear air-drying varnish (grade CA), which conforms to Military Specification, MIL-V-1137. After the varnish has dried, the coil ends are tinned to ensure a good connection to the commutator.

Preformed windings should be used on large armatures, but it is more practical to wind small armatures by hand. End room is very limited, and windings must be drawn up tightly to the armature core. Figure 7-34 shows the method of winding an armature by hand. One armature in the figure is small enough to be hand-held. The other, too heavy for this, rests on a support.

Placing Coils in Slots

Before assembling the coils insulate the armature core. This step is of extreme importance; if the armature contacts the coils, you will have to do your work over. Clean the core slots and ends, and true up the laminations. Use fish paper or fuller board for insulation, and let it extend 1/4 in. beyond the slots, to prevent the edges of the laminations from

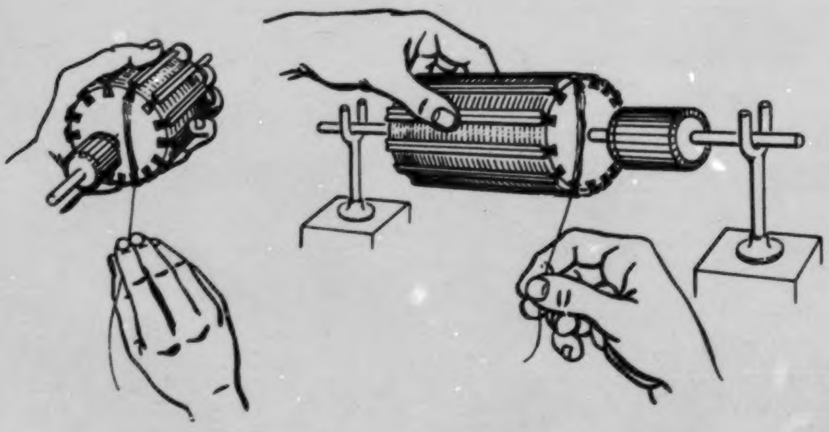
Table 7-1.—Varnishing procedure

Typical treating schedule.—The following treating schedule may be used as a guide in processing electrical windings. The baking time and temperature may vary depending on the type and grade of varnish used and the size of the winding being processed:

Armature coils, armatures, stators and field coils

	Class A, Class B and Class F systems	Class H and higher temperature systems
Step 1: Prebaking	Put into oven at 110°C (230°F). Hold at temperature for 4 hours. Cool to approximately 50°C (122°F).	Put into oven at 150°C (302°F). Raise temperature 50°C (122°F) per hour to a maximum of 200°C (392°F). Hold at temperature for 4 hours. Cool to approximately 50°C (122°F).
Step 2: Dipping	Immerse coils or wound apparatus in 40°C (104°F) in varnish until bubbling ceases. Viscosity shall be held between 150 to 250 centipoises. Thin Class A, Class B varnish with mineral spirits to maintain viscosity. Use xylene for Class F varnish.	Immerse coils or wound apparatus in varnish for not over 5 minutes. Varnish types or grades shall not be mixed. Viscosity shall be held between 125 to 225 centipoises. Thin with xylene to maintain viscosity.
Step 3: Draining	Drain and air dry for 1 hour. Rotate wound apparatus to prevent pocketing the varnish.	Drain and air dry for 1 hour. Rotate wound apparatus to prevent pocketing the varnish.
Step 4: Wiping	After draining but before baking the metal surfaces of the armature, the bore of the stator and the pole faces of the field structure must be wiped with a cloth moistened with solvent.	After draining but before baking the metal surfaces of the armature, the bore of the stator and the pole faces of the field structure must be wiped with a cloth moistened with solvent.
Step 5: Baking	Bake in a circulating type, forced-exhaust, baking oven at temperature of 150°C (302°F) for 6 to 8 hours.	Put into a circulating type, forced-exhaust, baking oven at temperature of 200°C (392°F) for 2 hours.
Step 6: Cooling	Remove from oven and cool to approximately 50°C (122°F).	Remove from oven and cool to approximately 50°C (122°F).
Step 7: Second treatment (dip in opposite direction).	Repeat steps 2 (immerse for 1 minute), 3, 4, 5, and 6.	Repeat steps 2 (immerse for 1 minute), 3, 4, 5, and 6.
Step 8: Third treatment (dip in original direction).	Repeat steps 2 (immerse for 1 minute), 3, 5, and 6.	Repeat steps 2 (immerse for 1 minute), 3, 5 (baking additional 8 hours at 230°C (446°F)) and 6.

111.82



73.233

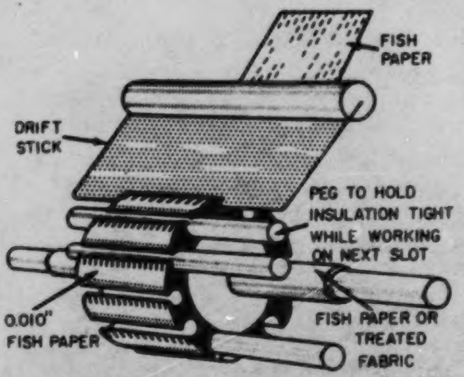
Figure 7-34.—Winding armatures by hand.

injuring the coils. Figure 7-35 shows a method of insulating the slots.

The ground insulation, consisting of flexible mica wrappers or layers of reinforced mica tape, is applied to the coil sides that lie in the slots. The formed coils are next placed in the slots, the lower side first and then the upper side, until all the coils are inserted and the winding is completed. Be certain that the coil pitch is correct. A strip of rigid laminate, type GME-MIL-P-15037, is placed in each slot between the lower and upper coil sides, and a similar strip is placed at the back and front of the armature where top and bottom sides cross each other. If the slots have straight sides, they are filled up with a strip of rigid laminate, type GME-MIL-P-15037, on the tops of the coils so that they can be held down by the banding wires. In some armatures the slots are shaped so that fiber wedges can be driven in each slot from one end to hold the coils in place.

Before soldering the coil ends to the commutator segments, test the winding for grounds, opens, shorts, and dead coils. Exercise care (when soldering) to prevent solder from falling or running down the back of the commutator, as this would result in a short circuit. Tip the armature so that the solder will not flow down the back of the commutator. Place the tip of the soldering iron on the commutator near the riser and wait until the iron heats the riser sufficiently to melt the solder. Touch the solder to the riser and allow it to flow down and around the lead and into the wire slot, and then remove the iron.

The ordinary soldering iron cannot supply sufficient heat fast enough to perform a satisfactory soldering job on a large armature. Therefore, apply a soft flame from an acetylene torch to the outside end of the commutator segments to the riser ends where connections are made. Tin the coil ends (to be connected to the commutator risers) with the soldering iron. Next, tin the slots in the commutator risers


FISH PAPER
DRIFT STICK
PEG TO HOLD INSULATION TIGHT WHILE WORKING ON NEXT SLOT
0.010" FISH PAPER
FISH PAPER OR TREATED FABRIC

73.232

Figure 7-35.—Continuous strip method of insulating slots.

with heat from the torch. Then make the connections while applying the flame to the outside end of the commutator segments. Wrap the winding in asbestos tape for protection (when making the commutator connections) because too much heat can damage the winding insulation. The completed armature winding is checked electrically for continuity and for shorted turns.

To prevent centrifugal force from throwing the coils outward, wind a band of high-grade steel piano wire on a strip of leatheroid, which is placed around the armature and over the coils about 2 inches from the edge of the core. This is done either before or after the armature has been dipped and baked.

It is preferable to place the banding wires on the armature while the windings are hot because the insulation shrinks when heated, is more flexible, and can be pulled down tightly much easier than when the armature is cold. When the first banding wire is wound on the armature, small tin clips, with insulation under them, are inserted under the wire. When the required number of turns has been applied, the ends of these clips are turned up over the wires to hold them tightly side by side. The clips are then soldered with a tin solder, and a thin coat of solder is run over the entire band to secure the wires together.

The end windings are secured, if necessary, by groups of wire wound on insulating hoods to protect the coils. On the commutator end, strips of thin mica with overlapping ends are usually placed on the commutator neck and held by a few turns of cord. On large armatures, banding wires are sometimes placed over the laminated portion of the armature. The laminations on these armatures have notches in which the banding wire is placed.

If it is necessary to rebuild a commutator, use molding micanite to insulate between the spider and the commutator. Commutator mica is used as insulation between the segments. After the commutator is assembled, it is heated and tightened with a clamping ring.

If shrink rings are provided, they are not put on until the commutator has been tightened (while hot) and the banding wires tightly placed around it. If defective, small commutators are usually completely replaced.

Insulating Materials

Current-carrying conductors require insulation for various reasons. An understanding of the different types of insulation used will be of help to you in the repair of electrical equipment. The different classes of insulation materials are listed in table 7-2.

There are certain conditions when the rewinding of Class A and B insulated motors with Class H insulation becomes necessary. This is done to prevent a recurrence of insulation breakdown and ultimate failure. Here are examples of such conditions:

1. Where the location ambient exceeds the equipment design ambient (usually 50° C).

2. Where excessive moisture (usually condensate) is present and the windings are exposed.

3. Where the service life of existing equipment is shortened by overload, heat, moisture, or a combination of these factors.

Silicone insulation is not a cure-all for motor and generator failures. Before deciding to use silicone insulation the installation should be checked to determine the cause of failure. Misalignment of bearings, mounting bolts dislocated, a bent shaft, failure or inoperativeness of overload devices or similar causes may have initiated the failure rather than the insulation itself.

Consideration must be given to the conditions to which the windings will be subjected during winding, varnishing, and drying out or baking. Class A, B, and F materials are generally tough and will take a lot of abuse. Class H and N materials are considered somewhat fragile and should be handled with care in order not to damage the resin film.

Varnishing

Prior to varnish treating, the windings or coils should be prebaked to remove all moisture. The windings or coils should be left to cool to a temperature not less than 10° C above room temperature prior to immersion in varnish. The windings or coils should remain in the varnish

Table 7-2.—Classes of insulation

CLASS INSULATION SYSTEM	CLASS MATERIAL	MATERIALS OR COMBINATION OF MATERIALS	REQUIRED THERMAL LIFE
A	105	Cotton, silk, and paper when suitably impregnated or coated, or when immersed in a dielectric liquid such as oil.	105°C
B	130	Mica, glass fiber, asbestos, etc., with suitable bonding substances.	130° C
F	155	Mica, glass fiber, asbestos, etc., with suitable bonding substances.	155°C
H	180	Silicone elastomer, mica, glass fiber, asbestos, etc., with suitable bonding substances such as appropriate silicone resins.	180° C
N	200	Mica, glass fiber, asbestos, etc., with suitable bonding substances.	200°C

11.132

until bubbling ceases. After dipping, the windings or coils should be allowed to drain and then are baked at the prescribed temperature for the time shown in table 7-2. Do not dip and bake more than three times. The baking ovens must be rated at 350° F for Class A, B, and F windings and 500° F for higher temperature windings and must be of sufficient capacity to maintain these temperatures at a full exhaust rate of two air changes per minute.

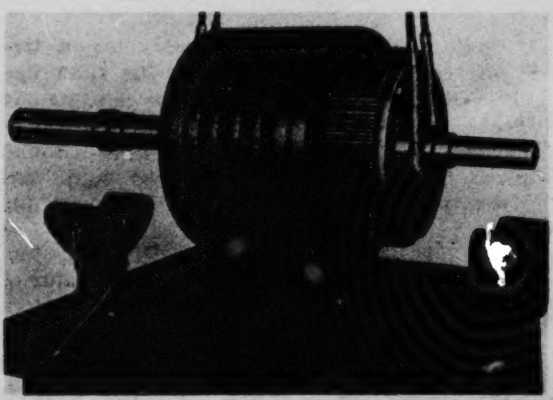


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Figure 7-36.—Applying insulating varnish to armature windings.

Separate dip and storage tanks should be provided for the silicone varnish, because silicone varnish is not compatible with other varnishes. No solder joints should be used on the tanks as solder may gel the varnish.

The d-c armatures should be dipped with the commutator end down to seal behind the commutator neck. The commutator can be wrapped to prevent varnish buildup. When draining, have the commutator upright. If the assembled winding cannot be immersed, it can be slowly rotated in a horizontal position in a shallow pan to allow the varnish to flow into the winding interstices (fig. 7-36). All winding parts should be well soaked during the immersion. At least two complete revolutions should be made, each revolution taking about 10 minutes. In the baking operation allowances should be made for the time necessary to bring the armature up to temperature. If possible, d-c armatures should be baked with the commutator end up.

The completed armature is now placed in a lathe and a very light cut taken over the surface of the commutator and over the face and side of the commutator risers to make the assembly perfectly true. Next, the commutator mica should be undercut so that the carbon brushes will not be damaged by the high mica.

You must remember that all armature stator and field windings must be checked for shorts, grounds, and opens after each step of being wound, formed, taped (if necessary), installed, connected, dipped, and baked.

High-Potential Tests

A high-potential test is made by applying (between insulated parts) a test potential that is higher than the rated operating voltage. High-potential tests are frequently used in connection with the repair or reconditioning of naval equipment ashore.

The purpose of the test is to break down the insulation if it is weak, thereby indicating defective material and workmanship, and permitting replacement prior to actual use.

The application of each high-potential test tends to weaken insulation even though it does not produce actual failure at the time. Also, the use of high-potential tests requires special equipment and safety precautions.

When making high-potential tests on electrical equipment that has been reconditioned or rewound in a shop, keep from coming in contact with any part of the circuit or apparatus. Never touch the winding after a high-potential test has been made until it has been connected to ground to remove any static charge it may have retained.

A high-potential test should not be made on a d-c generator or motor until after the reconditioning or rewinding is completed, including the application of varnish, and the insulation resistance has been measured and found to be higher than the value in the last column of table 7-3.

All leads to the circuit being tested should be connected to one terminal of the source of test voltage. All leads to all other circuits and all metal parts should be connected to ground. No leads are to be left unconnected for a high-potential test as this may cause an extremely severe strain, at some point of the winding. For example, to make a high-potential test on a rewound armature, short circuit the commutator segments by wrapping one or more turns of bare wire around the commutator and apply the high-potential test voltage across the common connection of all the commutator segments and the grounded armature shaft.

The high-potential test voltage is obtained from a 60-hertz a-c source that should have a capacity of 1 kilowatt. When making a test, increase the voltage as rapidly as possible without exceeding the correct value, as indicated on

Table 7-3.—Minimum Direct-Current Generator and Motor Insulation Resistances for High-Potential Tests

Circuit	Insulation Resistance in Megohms at 25°C,[1] After Reconditioning in Shop.
Complete armature circuit[2]	1
Armature alone	2
Armature circuit less armature[2]	2
Complete shunt field circuit[2]	2.5

[1] The figures given are for machines rated at 250 volts or less. For machines having a rated voltage, E, greater than 250 volts, multiply all figures given in the table by E/250.

[2] Small machines usually have one of the shunt field leads connected internally to the armature circuit. To avoid disassembly in such cases, the complete armature circuit and complete shunt field circuit may be measured without breaking this connection. If necessary, the armature can then be isolated by lifting all brushes.

(a) With the brushes left in place, the complete armature circuit will include armature, armature circuit, and the permanently connected shunt field circuit. The values given in the table for the complete armature circuit will apply.

(b) With the brushes lifted, the armature circuit less armature and the complete shunt field circuit will be measured. The values given in the table for armature circuit less armature will apply.

111.83

the voltmeter. The full voltage should be maintained for 1 minute. The voltage should then be reduced at a rate that will bring it to one-quarter of the correct value or less in not more than 15 seconds.

FIELD COILS

Preventive maintenance of field coils requires periodic inspections and tests to determine the condition of the coil. Coils should be cleaned periodically to remove any foreign particles which might have collected on them.

The insulation on field coils should be tested periodically to determine its condition. A resistance-measuring device may be used for this purpose. If a ground is detected in the field circuits (shunt, series, and interpole) of a d-c machine, the circuits must be disconnected from each other and tested separately to locate the grounded circuit. Then all the coils in that circuit must be opened and tested separately to locate the grounded coil, which can be repaired or replaced as necessary.

If an open circuit develops in the field windings of an a-c or d-c generator that is carrying a load, it will be indicated by immediate loss of load and voltage. An open in the shunt field winding of an operating d-c motor may be indicated by an increase in motor speed, excessive armature current, heavy sparking, or stalling of the motor. When an open occurs in the field circuit of a machine, it must be secured immediately and examined to locate the faulty circuit. The open circuit will usually occur at the connections between the coils and can be detected by visual inspection. An open in the coils generally causes enough damage to permit detection by visual inspection.

Rewinding Field Coils

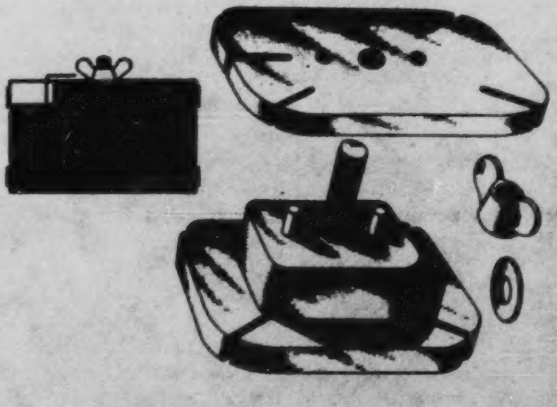
The old field coil is removed from the pole piece and, if spare coils are available, a new one is installed. If a new coil must be made, record all pertinent coil data as the old coil is stripped down.

This data should include the (1) dimensions of the coil, both with the tape on and with the tape removed, (2) weight of the coil without the tape, (3) size of wire, and (4) type of insulation.

The two general classes of coils are (1) shunt field coils, which consist of many turns of fine wire and (2) series and commutating field coils, which consist of fewer turns of heavy wire.

SHUNT COILS. — The equipment for rewinding shunt coils includes a lathe or suitable face plate, which can be turned at any desired speed, and an adequate supply of the proper size wire wound on a spool, which can be supported on a shaft so that it is free to turn. Friction should be applied to the spool to provide tension on the wire. A coil form having the exact inside dimensions of the coil is secured to the lathe or face plate. The form for shaped field coils can be made from a block of wood shaped exactly to the required size and provided with flanged ends to hold the wire in place (fig. 7-37). One of the flanges should be removable so that the finished coil can be taken from the forming block.

The wire is now wound from the spool onto the forming block for the required number of turns. The turns must be evenly spaced, one against the other, until the winding procedure is completed. The turns of the completed coil are secured by tape, and the wire leading to the spool is cut, leaving sufficient length to make the external connections. The completed coil must be checked electrically for continuity and for shorted turns.



77.81

Figure 7-37. — Coil form for field coils.

The coil is now prebaked and varnish treated. When varnish treated, the finished field coil should withstand a high-potential test of twice the rated excitation voltage +1,000 volts.

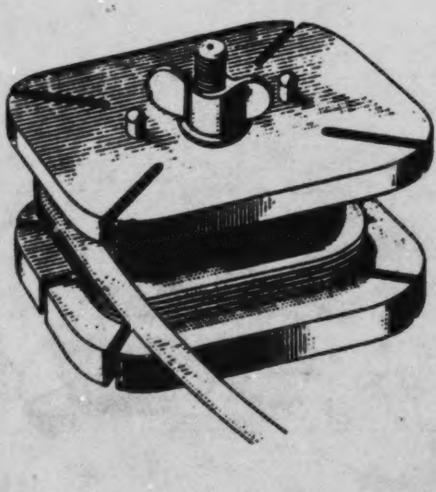
SERIES AND COMMUTATING COILS. — Series and commutating field coils are frequently wound with strap (rectangular) or ribbon copper instead of round wire. These coils have only a few turns that are wound in a single turn per layer.

A series coil wound (with ribbon copper) on edge is illustrated in figure 7-38. It is more difficult to bend the copper ribbon, but it has an advantage in that both terminal leads protrude on opposite sides of the coil. Thus, the connections can be made very easily compared to the strap-wound coils, which have one coil end at the center and the other coil end at the outside of the coil. The strap-wound construction requires leading the inside coil end over the turns of strap in the coil.

After the winding is completed, the coil is tested electrically for continuity and shorted turns. It is then prebaked, varnished, and tested for polarity, grounds, opens, and shorts as described previously, at each stage in turn.

Compass Aids

Before installing a new or repaired coil, it should be tested for shorts, opens, and grounds and its polarity determined. A small magnetic compass may be used to determine the polarity of a field coil by holding it several inches away from the coil along its axis (fig. 7-39). A small battery is connected to the coil leads, and if the south compass needle points toward the center of the coil, the face of the coil nearest the compass will be a north pole. This will indicate that the coil should be placed on a north pole in the same position it was in during the test, and the field current should flow through the coil in the same direction.



77.84
Figure 7-38. — Edge-wound series coil.

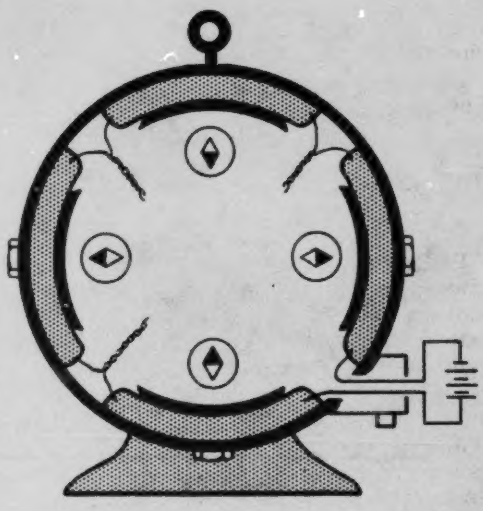


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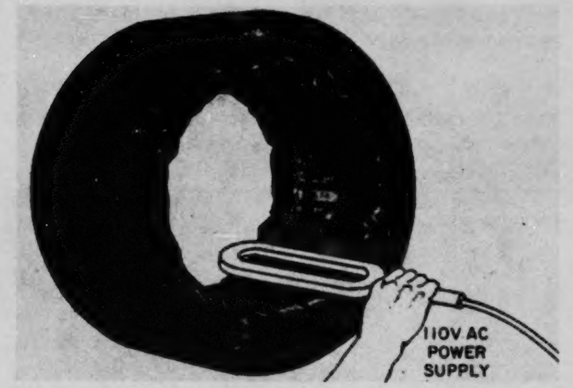
Figure 7-39. — Testing polarity of field coils.

To protect the armature, the same precautions that were observed during removal of the coil must be observed when installing it. All of the shims originally removed from the pole piece must be in position when it is replaced. With the coil in position in the machine, it should be temporarily connected to the other coils in the field circuit and a compass and battery again used to check its polarity. For this test, connect the battery to the proper field leads and check the polarity of all the coils with the compass (fig. 7-39). Adjacent poles must be of opposite polarity. If need be, polarity of the new coil can be reversed by reversing its leads. When the polarity is correct, the coil is connected, and the pole-pieces bolts are tightened. Air gaps should be measured to ensure uniformity.



73.147

Figure 7-40.—Testing a three-phase stator for shorted coils.

ALTERNATING-CURRENT STATOR COILS

Alternating-current stator windings require the same careful attention as other electrical windings. For a machine to function properly, the stator windings must be free from grounds, short circuits, and open circuits. Frequent tests and inspections are necessary to determine the condition of the windings, and they must be kept clean to preserve the insulation.

A short circuit in the stator of an a-c machine will produce smoke, flame, or the odor of charred insulation. The machine must be secured immediately.

Open circuits in a-c stator windings can sometimes be found by visual inspection because the open is usually the result of damaged connections where the coils and circuits are connected together. Should visual inspection fail, resistance measurements between the phase terminals will reveal the presence of open-circuited coils. The coil ends in the faulty phase are tested with an ohmmeter to locate the open-circuited coil. When the open circuit is in an inaccessible location and cannot be reached for repairs, the machine can be repaired for emergency use by cutting out the faulty coil.

Grounds in a-c stator windings can be detected with a megger or similar resistance-measuring instrument. Both ends of each phase are opened and tested to locate the grounded phase. Then, each circuit in the grounded phase is opened and tested to locate the grounded circuit. Finally, the ends of each coil in the grounded coil are located.

Shorted coils are identified readily if an internal growler is used. This instrument has an attached blade which is run over the stator coils (fig. 7-40). Transformer action causes a growling noise when a shorted coil exists.

It is most important to keep an accurate record of all the pertinent data concerning the winding on the stator data sheet, as shown in figure 7-41. If possible this information should be obtained before stripping; if not, it can be obtained during the stripping operation.

An a-c stator is stripped in the same manner as a d-c armature. Exercise care to preserve one coil in the original shape to provide the dimensions for the new coils if spare coils are not available and it is necessary to rewind them. Be certain to measure the end room of the coils before they are removed from the slots. Record this distance on the data sheet and be sure that the new coils do not extend beyond this distance from the ends of the slots. The winding should be preheated in an oven to soften the varnish and thus facilitate stripping. The end connections, preferably at the lead end, are then cut and the coils removed from the slots by pliers or a screwdriver.

After the stator is stripped, inspect the laminations for alignment and especially for sharp

Make

H.P.	R.P.M.	Volts	Amps.
Hertz	Type	Frame	Style
Temp.	Model	Serial	Phase

No. of Coils	No. of Slots	Connection
Size Wire	No. of Turns	No. of Groups
Coils/Group	No. of Poles	Pitch of Coil

111.65

Figure 7-41.—Stator data sheet.

burrs protruding from the end laminations. The stator should be cleaned of all dirt, grease, rust, and scale. The stator, similar to the d-c armature, is then varnish-dipped and baked, using a dilute varnish of the same type that is used after winding.

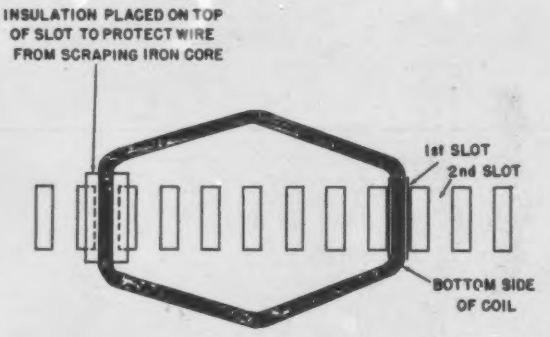
The windings of stator coils are usually prewound and preformed (formed coils) on a machine. The size and shape of the coils are best determined from the coil that was removed from the stator intact. After the coil is wound, it is tied in several places to hold the turns together. The two wires forming the leads are taped or sleeved with glass braided sleeving. The excess insulation is removed from the free ends of each coil, which are then tinned. The individual coils are then checked electrically for continuity and for shorted turns.

Placing Coils in Slots

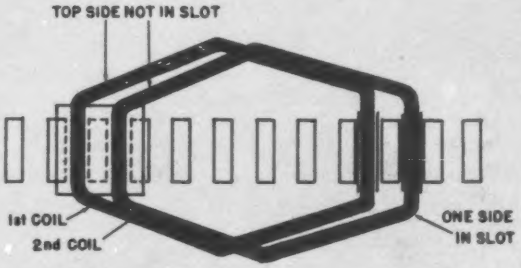
The coils to be inserted in open slots have the entire surface taped, and the coil sides are placed in each slot intact. The right side of the coil, which occupies the bottom half of the slot, is inserted first (fig. 7-42). The free end coming from this side is known as the bottom lead of the coil. The left side of the coil, which occupies the top half of another slot, remains free. Continue by placing the right side of the second coil in slot 2 adjacent to slot 1. The remaining coils are inserted in this manner until the slots spanned by a complete coil pitch each contain the right side of a coil. The left side of each coil remains out of the slot until the bottom half of the slot is occupied by the right side of a coil. Continue around the stator, and then insert the left side of each coil on top of the right side of a coil several slots away, depending on the coil pitch.

Before inserting the side of the second coil in a slot, insulate it from the first coil's side already in the slot. This is done by placing a strip of insulation over the bottom coil.

Be certain that each coil side extends beyond the slot at both ends and does not press against the stator core at the corners. The phase insulation consisting of varnished cambric is placed between the phase groups because of the high voltage existing between phases. The computations indicated under interconnection of phases should be completed before any coils are inserted in the stator to allow for this extra insulation.


INSULATION PLACED ON TOP OF SLOT TO PROTECT WIRE FROM SCRAPING IRON CORE
1st SLOT
2nd SLOT
BOTTOM SIDE OF COIL

FIRST COIL OF WINDING IN PLACE



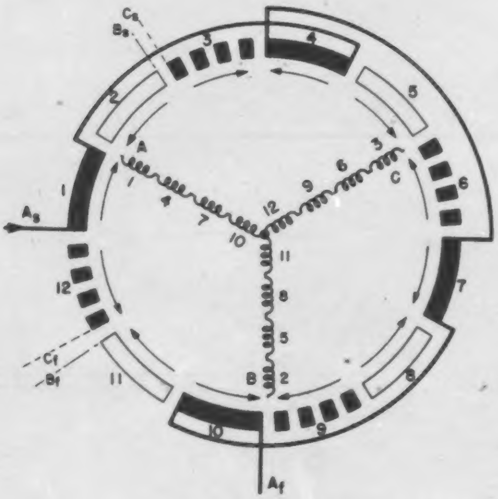
SECOND COIL OF WINDING IN PLACE

111.66

Figure 7-42.—Placing coil sides in slots.

After the stator coils are all in place, force the coil sides down in the slots by placing a piece of soft wood or fiber on top of the coils through the slot opening, and gently tapping on it. When the coils are securely in the slots, insert the slot wedges to hold the coils in place. The wedges consist of flat melamine laminates machined to shape.

When all the coils have been inserted in the stator slots, the ends insulated, and the slot wedges driven in place, there will be two free ends for each coil (top and bottom) from one side of the stator winding. The free ends must



111.67
Figure 7-43.—Three-phase 4-pole winding for a 36-slot stator.

be connected to form a series of groups of coils.

You can compute the number of coils in a group by dividing the number of coils in the stator by the number of pole-phase groups. For example: if the stator has 36 slots and 36 coils, and if there are 4 poles and 3 phases, you will have 3 coils in series in each group. The number of poles multiplied by the number of phases gives the number of pole-phased groups.

To connect the pole-phase groups together, you should have a diagram similar to figure 7-43. Mark with arrows the direction of the current flow through each pole-phase group. The current flow must reverse in direction for each successive group so that there will be alternate north and south poles.

In arranging these coils into pole-phase groups, start by bending (forming) the inside lead of the first coil in toward the center and then connect the outside lead of that coil and the inside lead of the next coil together. Connect the outside lead of the last coil with the inside lead of the next coil and bend the outside lead of this coil away from the center. Repeat this procedure for each of the pole-phase groups all around the stator. Do not solder the connections at this time.

After twisting the ends together, check the individual groups to determine that the proper number of coils have been connected together in each pole-phase group and that they have the proper polarity. Then solder the twisted connections and cut off the ends so that the soldered stubs are about three-quarters of an inch long. Insulate the stubs with cotton tape or reinforced mica tape.

If the distance to the bearing brackets (frame of the machine) is small, bend the insulated stub in between the coils so that they do not come in contact with the frame when the stator is assembled in the machine.

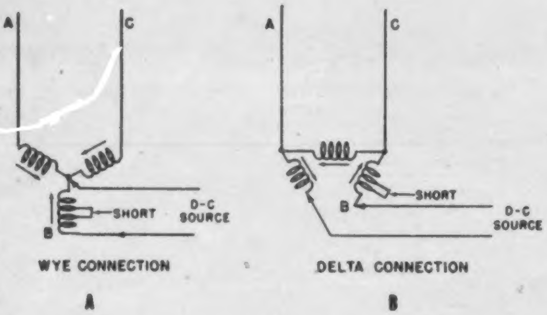
In practice, the coils that comprise the pole-phase groups are usually gang wound. Gang wound coils eliminate the need for stubbing, because the coils are wound with a continuous length of wire.

Polyphase Stator Troubles

In troubleshooting rewound and reconnected polyphase stator windings, you are likely to find that the trouble is a short in a pole-phase group or an entire phase, or that a winding is open circuited.

SHORTED POLE-PHASE GROUP.—An entire pole-phase group may be shorted in a polyphase stator. Such a defect is usually indicated by excessive heat in the defective part. The trouble can be readily located by a compass test. To conduct a compass test, excite the stator windings with a low-voltage, direct current that will set up the poles in the stator (fig. 7-44). When the windings are excited, a compass is moved around the inside circumference of the stator core. As each pole group is approached, the polarity is indicated by the compass. There should be the same number of alternate north and south poles in a 3-phase winding.

In a 3-phase, wye-connected winding (view A, fig. 7-44), test each phase separately by impressing the d-c voltage successively on each of the phase leads and the midpoint of the wye connection. If there is no trouble in the winding, the compass will indicate alternately north and south for each pole-phase group around the stator. If a complete pole-phase group is shorted, the compass needle will not be deflected at this point.

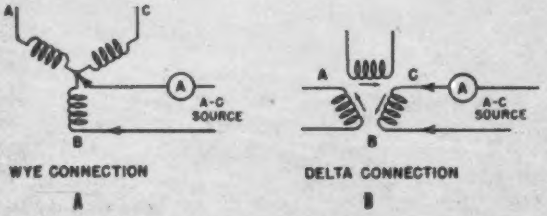

A
C
SHORT
D-C SOURCE
B
WYE CONNECTION
A
A
C
SHORT
B
D-C SOURCE
DELTA CONNECTION
B

111.76
Figure 7-44.—Compass test for shorted pole-phase groups.

In testing a 3-phase delta-connected winding (view B of fig. 7-44), open one of the delta connections and apply the direct current to the winding. The current will flow through the three phases in series. If the pole-phase groups are connected properly, the compass will indicate alternate north and south poles around the stator frame. As in the wye-connected winding, a shorted pole-phase group is indicated by no deflection of the compass needle.

SHORTED PHASE.—When an entire phase of a 3-phase winding is shorted, the defect is most readily located by a balanced-current test made with an industrial analyzer.

This test can also be made with an ammeter and low-voltage a-c source. In testing a 3-phase wye-connected winding (fig. 7-45, view A), test each phase separately by impressing the a-c voltage successively on each of the phase leads and the midpoint of the wye connection. If there is no trouble in the windings, and if the impedance of the winding of each phase is the same, the ammeter will indicate approximately the same value of current for each of the three phases. If one phase is shorted, the ammeter will indicate a higher current reading for this phase than those of the other two phases because the impedance is less.

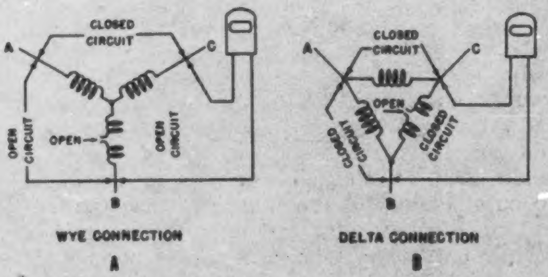

A
C
A
A-C SOURCE
B
WYE CONNECTION
A
A
C
A
A-C SOURCE
B
DELTA CONNECTION
B

111.77
Figure 7-45.—Balanced current test for shorted phase.

In testing a 3-phase delta-connected winding (fig. 7-45, view B), open each delta connection and test each phase separately. As in the wye-connected winding, the shorted phase will be indicated by a much higher current reading on the ammeter.

OPEN CIRCUITS.—An open circuit in a 3-phase winding can be readily located by means of an ohmmeter. In testing a 3-phase wye-connected winding (fig. 7-46, view A), connect the ohmmeter leads across each of the phases to locate the defective phase. When the ohmmeter leads are placed on terminals A and C, no open circuit (a low reading) is indicated. However, when the leads are placed on terminals C and B, and then on terminals B and A, an open circuit (a high reading) is indicated in both positions, thus denoting an open in phase B. After the defective phase has been located, test each stub connection of the pole-phase groups with the ohmmeter until the open coil is located.

In testing a 3-phase, delta-connected winding (fig. 7-46, view B), it is necessary to open one delta connection to avoid shunting the phase being tested. Test each phase separately until


CLOSED CIRCUIT
A
C
OPEN CIRCUIT
OPEN
OPEN CIRCUIT
B
WYE CONNECTION
A
CLOSED CIRCUIT
A
C
OPEN
CLOSED CIRCUIT
CLOSED CIRCUIT
B
DELTA CONNECTION
B

111.78
Figure 7-46.—Ohmmeter test for open circuits.

Single Phase ☐ **Capacitor** ☐ **Split Phase** ☐

H.P.	Hz	Type	Style
R.P.M.	Volts	Model	Ser. No.
Make	Amps	Frame	Cap MFD
Rotation facing shaft	Clockwise ☐ Counter-Clockwise ☐	No. Poles	No. Slots

Winding	No. Coils Per Pole	Turns Per Pole	Inside Coil Span	Size Wire	Type Wire	No. Circuits	Coil Extension
Running							
Starting							

Stator Dimensions	
Inside Diameter	
Length of Core	
Depth Iron Behind Slot	

Running																		
Slot No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Starting																		

111.65

Figure 7-47.—Single-phase motor data card.

the open is located. After the faulty phase is located, test each stub connection of the pole-phase groups, as in the wye-connection, until the open coil is located.

If the windings are parallel, it is necessary to open each parallel group and test each group separately.

MOTOR AND GENERATOR MAINTENANCE

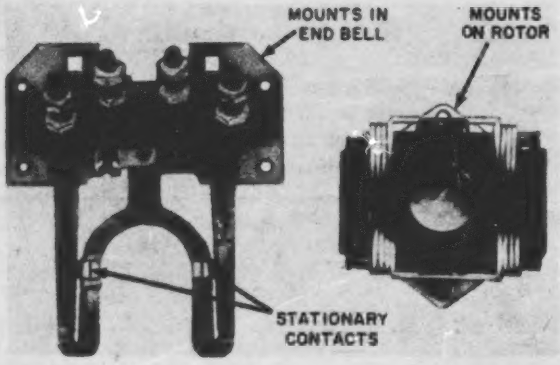
There are many applications for single-phase motors in the Navy. They are used in interior communication equipment, refrigerators, fans, drinking fountains, portable blowers, portable tools, and in many other applications. Single phase motors are considerably cheaper in fractional horsepower sizes, but above 1 horsepower the 3-phase motors are less expensive. The use of single-phase motors also eliminates the need of running three wire service to supply small loads.

In Basic Electricity, NAVPERS 10086-B, chapter 17, there is a section devoted to single-phase motors. A check of this section would help you in reviewing the theory of operation of single-phase motors.

Steps in analyzing motor troubles should proceed in a logical sequence to determine what repairs are required for reconditioning the motor: (1) Inspect the motor for defects, such as, cracked end bells, bent shaft, broken or burned wiring; (2) check the motor for bearing troubles; (3) test the motor for grounds, opens, and shorts (see armature and 3-phase stator sections). If rewinding is required, record the necessary data on a motor data card (fig. 7-47).

CENTRIFUGAL SWITCHES

Burnt starting windings and defective centrifugal switches are frequently the causes of inoperative single-phase motors. Figure 7-48 shows the two major parts of a centrifugal switch. The centrifugal switch is located inside the motor on the rear end bell. It is used to disconnect the starting winding after the rotor has reached a predetermined speed, usually 75 percent of the full load speed. The action of the



73.130
Figure 7-48.—Two major parts of a centrifugal switch.

centrifugal switch is as follows: The contacts on the stationary part of the switch (the stationary part is mounted on the end bell) are closed when the motor is not in motion and completes the circuit through the starting winding. When the motor is energized and reaches approximately 75 percent of full load speed, the rotating part of the switch (mounted on the rotor) is forced by centrifugal force against the stationary arm, thereby breaking the contact and disconnecting the starting winding from the circuit. The motor is then operating on the running winding as an induction motor (fig. 7-49).

When a motor is overloaded, the speed slows and allows the centrifugal switch to energize the starting windings, then the motor speeds up enough so that the centrifugal switch opens the starting circuit again. This constant opening and closing of the starting winding circuit will cause the failure of the winding.

The condition of the switch must be checked periodically to determine that the switch contacts are clean and that all moving parts function properly. Stalling while starting or failure to start may indicate a faulty centrifugal switch. If this happens, power to the motor must be secured immediately or the starting winding will soon overheat and burn out.

SPLIT-PHASE MOTORS

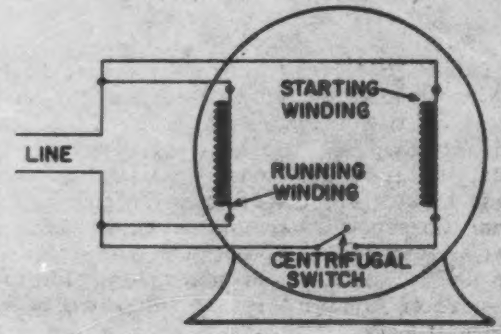
To analyze troubles in a split-phase motor, the first check after the obvious physical checks have been made, is for appropriate voltages at the terminal block. The next check is for grounds, shorts, or opens. Check to see if the rotor revolves freely. If the rotor turns freely when no voltage is applied, but locks when energized, you will know that the bearings are worn enough to allow the iron in the rotor to make contact with the iron in the pole pieces.

CAPACITOR MOTORS

The capacitor motor is similar to the split-phase motor except that it has a capacitor installed either on top of the motor, on the end of the frame, inside the housing, or even remote from the motor.

A capacitor-start motor does have a centrifugal switch for removal of the starting winding when the rotor has reached 75 percent of its rated speed. The capacitor-run motor does not have this switch. The starting winding stays in the circuit continuously.

The procedure for repair and troubleshooting capacitor motors is the same as it is for the split-phase motor except, of course, for the capacitors. Before applying the leads of a capacitor, disconnect the power and be sure to discharge the capacitor terminals. Upon completion of the tests, BE SURE TO DISCHARGE THE CAPACITOR TERMINALS. Replace the capacitor, if tests indicate a defective capacitor, with an identically rated capacitor.

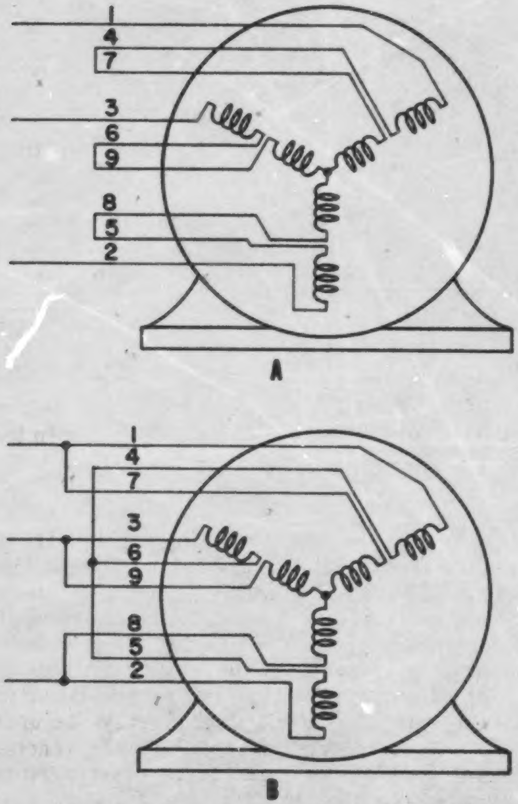


73.131
Figure 7-49.—Connections of a split-phase motor.

3-PHASE MOTORS

The windings in a 3-phase induction motor consist of coils, groups, and phases. For the 4-pole motor (the most common type), there are 36 slots and 36 coils. These coils are placed three coils to a group, three groups to a pole. Each of the three groups in a pole constitutes a phase. Phases are lettered A, B, and C.

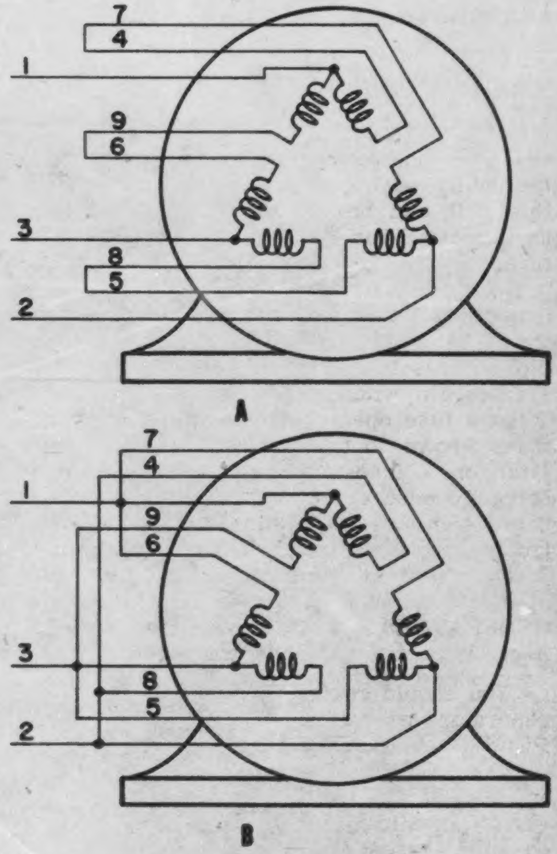
Coils or groups of coils can be connected in various ways, such as series delta, parallel delta, series star and parallel star. Figure 7-50 shows a star-connected motor, with series connection for higher voltage in view A, and parallel connection for lower voltage in view B. Most 3-phase motors are connected for dual voltage with nine leads brought out to the terminal box on the motor, so that the coils can be connected in parallel for the low voltage or in series for the higher voltage. The choice between star or delta connection therefore depends on the voltage available from the power source.



4-5-6 CONNECT AND INSULATE

73.143

Figure 7-50.—Star-connected motor.(A) Series; (B) Parallel.



73.144

Figure 7-51.—Delta-connected motor. (A) Series; (B) Parallel.

Figure 7-51 shows a delta-connected motor, with series connection for higher voltage in view A and parallel connection for low voltage in view B.

Checking for trouble in a 3-phase motor follows the same procedure as that used for a single-phase motor, except that the 3-phase motor has more coils to check for grounds, shorts, and opens.

First isolate the trouble as to phases, then open the connections in the particular phase to separate the groups and check again. When the faulty group has been located, open the connections of the three coils in the group to locate the faulty coil. For an emergency connection, this coil can be cut out in the same manner as described for cutting out a coil in the armature.

With a 3-phase motor, one fuse can open and the motor will keep running (with less power and more current). When the motor stops, it cannot start again with the opened fuse in the line. When a fuse opens, replace all three fuses with fuses known to be good, and test the old fuses later on a fuse-testing circuit at the electric shop. To ensure that all possible trouble points have been covered, it is a good idea to follow a troubleshooting checkoff list.

GENERATORS

You should review the information regarding generators presented in Basic Electricity, NAVPERS 10086-B. Any time you are required to work on any generators, be sure to consult the appropriate technical manuals. These list a variety of difficulties you may encounter, some possible causes, and repair methods.

CLEANING MOTORS AND GENERATORS

The importance of keeping all insulation clean must be emphasized. Dust, dirt, and foreign matter (carbon, copper, mica, and so on) tend to block ventilation ducts and increase resistance to the dissipation of heat, causing local or general overheating. If the particles are conducting or form a conducting paste through the absorption of moisture or oil, the winding may be eventually short circuited or grounded. Abrasive particles may puncture insulation; iron dust is particularly harmful since the dust is agitated by magnetic pulsations.

The four acceptable methods of cleaning motors and generators are wiping, use of suction, use of compressed air, and use of a solvent.

Wiping with a clean, lint-free, dry rag (such as cheesecloth) is effective for removing loose dust or foreign particles from accessible parts of a machine. When wiping, do not neglect such parts as the end windings, mica cone extensions at the commutator of d-c machines, slip-ring insulation, connecting leads, and terminals.

The use of suction is preferred to the use of compressed air for removing abrasive dust and particles from inaccessible parts of a machine because it lessens the possibility of damage to insulation. If a vacuum cleaner is not available for this purpose, a flexible tube attached to the suction side of a portable blower will serve as a satisfactory substitute. Always exhaust the blower to a suitable sump or overboard when used for this purpose. Grit, iron dust, and copper particles should be removed only by suction methods whenever possible.

Compressed air must be clean and dry when used for cleaning electrical equipment. Air pressure up to 30 pounds per square inch may be used on motors or generators. A throttling valve should be used on air lines that carry higher pressure than is suitable for blowing out a machine. Before the airblast is turned on the machine, any accumulation of water in the air pipe or hose must be thoroughly blown out, and both ends of the machine must be opened to allow a path of escape for the air and dust. The use of compressed air will be of small benefit if the dust is not suitably removed from the machine. The most suitable method is to attach a suction blower to an opening in the opposite end from the air jet to remove the dirt-laden air.

The use of solvents for cleaning electrical equipment should be avoided whenever possible; however, their use is necessary for removing grease and pasty substances consisting of oil and carbon or dirt. Alcohol will injure most types of insulating varnishes and should not be used for cleaning electrical equipment. Solvents containing gasoline or benzine must not be used for cleaning purposes under any circumstances. Carbon tetrachloride is not to be used because of its extremely high toxicity.

Approved Solvents

Inhibited methyl chloroform (trichloroethane), FSN GM 6810-664-0388, is one of the principal approved solvents for cleaning electrical equipment but liberal ventilation must be provided by exhaust fans or portable blowers if this solvent is used for more than a few minutes.

In the rare cases when means of ventilation are impractical, an air line respirator or oxygen breathing apparatus (OBA) must be used if exposure to the solvent vapors is for more than a few minutes.

Inhibited methyl chloroform is very corrosive in its action on metal and may prove injurious to certain insulation. Before using any solvent, apply it to a small area or sample of the insulation to be cleaned. If it injures the insulation, do not use it. Clean freshwater, preferably warm or hot, may be used as an emergency substitute for inhibited methyl chloroform. Water should be used only as an emergency substitute and the equipment must be thoroughly dried after any application of water.

Do not spray inhibited methyl chloroform on windings. It will collect in pools and do more harm than good. The solvent should be applied by moistening a lint-free cloth with the fluid and lightly rubbing the surfaces to be cleaned; repeat the process if necessary to loosen the dirt. After wiping the insulation with solvent it should be thoroughly dried with a clean lint-free cloth.

Inhibited methyl chloroform is detrimental to good commutation and should be kept from coming in contact with the commutator or brushes of d-c machines.

Inhibited methyl chloroform should never be used on hot equipment as the accelerated evaporation will increase the toxic hazards.

Trichloroethylene (FSN G6810-184-4794) is another approved solvent widely used in a vapor process for degreasing metals. It should not be used for cleaning electrical insulation because of its strong solvent action on these materials. The toxic effects of trichloroethylene are similar to those of inhibited methyl chloroform.

Dry cleaning solvent, type II (FSN W6850-274-5421), is an approved safety type solvent. The fire and health hazards of this solvent have been minimized. The efficiency of this solvent is somewhat less than the previously discussed chlorinated solvents but the hazards to personnel are also reduced.

Precautions

During the use of any solvent the following precautions must be observed:

Guard carefully against fire.

Use vapor-proof or watertight portable lights if supplementary lighting is required.

Have fire extinguishers available for immediate use.

Prevent possible sparks caused by one metallic object striking another.

If a spray or atomizer (not normally used for routine cleaning) is used, ground the nozzle.

Avoid saturation of the operator's clothing with the solvent.

Provide liberal ventilation by means of exhaust fans or portable blowers.

When using inhibited methyl chloroform or trichloroethylene, protect against breathing the fumes (a chemical cartridge respirator such as a gas mask will not prevent suffocation since the vapors from these solvents displace air and oxygen). Cleaning should be done under the observation of someone familiar with artificial respiration.

Do not apply solvents on hot equipment or in the presence of open flames. The chlorinated solvents form highly toxic phosgene gas on contact with open flame.

No less than two persons should be assigned to cleaning operations in a single compartment.

General signs of fume poisoning by chlorinated hydrocarbons include headache, nausea, mental confusion, and in some instances a kind of drunken behavior similar to that caused by alcohol. When any of the above symptoms are observed, the person should immediately be removed from the toxic atmosphere to fresh air or a well-ventilated space.

Wear rubber gloves when constant contact of approved solvents is unavoidable. The solvents dry out the skin and cause it to crack and bleed.

GENERAL MAINTENANCE

The essential points in the maintenance of electric generators and motors are: keep insulation clean and dry and of high resistance, keep electrical connections tight, and keep machines in good mechanical condition.

Keep all small pieces of iron, bolts, and tools away from the machines. Where it is necessary to do any soldering, make sure that no drops of solder get into the windings and that there is no excess of solder on soldered joints which may later break off due to vibration and fall into the windings.

Do not disturb the commutator clamping bolts on d-c machines. Interference with these may make it necessary to turn or grind the commutator to restore it to service.

Other bolts and mechanical fastenings on both the stationary and rotating members should be tightened securely when the machine is installed, checked after the equipment has run for a short time, and thereafter checked at regular intervals to make sure that they are tight. Particular attention should be given to the bolts used to clamp any insulation.

If an inspection of a rotor shows that there is looseness of keys, bolts, or other fastenings, a check should be made for evidence of damage due to this looseness. Such looseness may result in worn dovetail keys, damaged windings, or broken dovetails on the end plates. Two or three drivings (with a punch and hammer) usually will ensure the tightness of the keys, but they should be checked regularly.

The banding wire on d-c armatures should be checked at regular intervals to make sure that it is tight.

The outboard bearing on some generators (both a-c and d-c) is electrically insulated from the frame; or the bearing pedestal is insulated from the base and the bearing oil piping to prevent the flow of shaft currents through the bearing. In the former case, insulation is accomplished by means of a shell of insulating material installed between the bearing shell and the bearing housing. In the latter case, the bearing insulation is accomplished by using insulating shims under the pedestal and insulated holding down bolts and dowels. Also insulated couplings are provided in the bearing inlet and outlet oil piping flanges (for force feed bearings). Special attention should be taken to ensure that this insulation is not damaged or that conducting paths around this insulation are not inadvertently provided. For instance, care should be taken when painting machines furnished with insulated pedestals not to paint over the insulating shims, washers, and oil piping couplings. Bearing currents, if of sufficient magnitude, will rapidly ruin a bearing. These currents are caused by electromotive force generated in the shaft and structural parts of a generator unless it is carefully designed and constructed to minimize their occurrence. An insulated bearing (or pedestal) breaks the circuit and protects the bearings from damage so long as the insulation is effective.

Inspect all electrical connections (particularly terminals and terminal board connections) at frequent intervals to make sure they are tight. Loose connections result in increased contact resistance and increased heating which may result in breakdown. Use locknuts, lockwashers, or other means to lock connections which tend to become loose because of vibration. Inspect soldered terminal lugs for looseness or loss of solder, and tighten solderless terminal lugs occasionally. When electrical connections are opened, clean all oil and dirt from contact surfaces before reconnecting. If the contact surfaces are uncoated copper, sandpaper and clean immediately before joining. If the contact surfaces are silverplated, do not use sandpaper. Use silver polish or a cloth moistened slightly with an approved solvent. Coat the finished joint with insulating varnish. Steel bolts for making electrical connections should be zinc- or cadmium-plated. Make sure that exposed electrical connections are adequately insulated to protect against water and moisture and injury to personnel. This applies especially to exposed connections at terminal straps extending outside the frames of propulsion motors and generators.

Lubrication

IMPROPER GREASING PROCEDURES ARE A FREQUENT CAUSE OF DAMAGE TO ROTATING ELECTRICAL MACHINERY PROVIDED WITH GREASE-LUBRICATED BALL BEARINGS. The trouble is generally caused by forcing an excessive quantity of grease into the bearing housing, with either one or both of the following results:

1. Grease is forced through the bearing housing seals and onto the windings and, in the case of d-c machines, onto the commutators where it causes deterioration of insulation, and eventually results in grounds or short circuits.

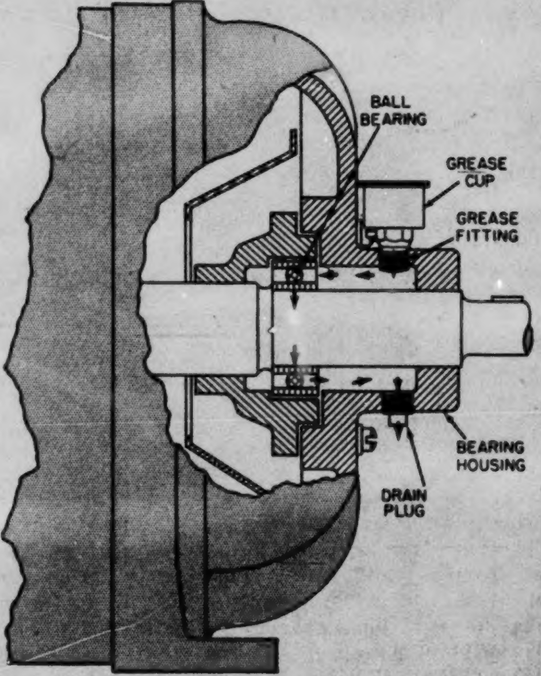
2. The excessive quantity and pressure of grease in the bearing housing result in churning, increased temperatures, rapid deterioration of the grease, and ultimate destruction of the bearing.

The following instructions apply to equipment except oil-lubricated bearings, synchros, and similar devices where friction must be maintained at an absolute minimum, and equipment for which approved lubrication charts or other specific instructions are furnished by the Navy. Except for the equipment to which they do not apply, the following instructions should be carefully observed in order to avoid failure of electrical equipment because of improper greasing practices:

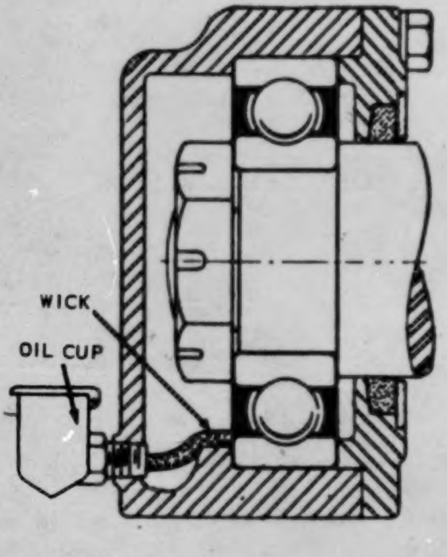
Motors and generators provided with bearings that should be lubricated with grease are now normally delivered from the manufacturer with the grease cups removed from the bearing housings and replaced with pipe plugs. The grease cups are delivered with the onboard repair parts or special tools. It is recommended that grease cups (fig. 7-52) be attached to electric motors and generators only when the bearings are being greased. When the grease cup is removed from the bearing housing after a bearing has been greased, the hole which remains should be plugged with a suitable pipe plug. When this procedure is used, the grease cups should remain in the custody of responsible maintenance personnel and can be stored in the workshop or toolroom. This procedure is particularly advantageous when the motors and generators maintained by a particular group of maintenance personnel need only relatively few different sizes of grease cups. This procedure should also be followed for motors and generators which have been supplied with grease cups attached to the machine. CARE SHOULD BE TAKEN TO MAKE SURE THAT A GREASE CUP IS CLEAN BEFORE IT IS USED TO ADD GREASE TO A BEARING AND THAT THE PIPE PLUG USED TO REPLACE THE GREASE CUP AFTER GREASING IS ALSO CLEAN.

Some electric motors and generators may be equipped with oil-lubricated ball bearings. Lubrication charts or special instructions are generally furnished for this type of bearing and should be carefully followed by personnel maintaining the equipment. In the absence of other instructions, the oil level inside the bearing housing should be maintained approximately level with the lowest point of the bearing inner ring. This will provide enough oil to lubricate the bearing for a considerable operating period, but not enough to cause churning or overheating.

One common method by which the oil level is maintained in ball bearings is the wick-fed method. In this method, the oil is fed from an oil cup to the inside of the bearing housing through an absorbent wick, which also filters the oil and prevents leakage through the cup in the event momentary pressure is built up within the housing. A representative wick-fed, oil-lubricated ball bearing is shown in figure 7-53.



77.68
Figure 7-52.—Grease-lubricated ball bearings.



77.69
Figure 7-53. — Wick-fed ball bearings.

The frequency with which grease must be added depends upon the service of the machine and the tightness of the housing seals, and should be determined for each machine by the engineer officer. Ordinarily, the addition of grease will not be necessary more often than once every 6 months. When a bearing housing is too full of lubricant, the churning of the grease generates heat which in turn causes deterioration of the grease. Under these conditions the grease separates into oil and minute abrasive particles, becomes increasingly stickly, and tends to seal the bearing against fresh lubricant until the resulting friction, heat, and water cause failure of the bearing.

Greasing Procedures

Bearings which normally operate at a temperature of 194° F (90° C) or below should be lubricated with grease in accordance with Military Specification MIL-G-18709, Stock Nos. W9150-235-5544 and W9150-235-5564.

To avoid the difficulties caused by an excessive amount of grease, add it only when necessary. Grease is added according to the following instructions:

1. Run the machine to warm up the bearings.

2. Wipe the outside of the grease fitting and drain the plug free of all dirt.

3. Remove the bearing drain plug, and make sure the passage is open by probing with a clean screwdriver or similar implement.

4. Remove the pipe plug on top of the grease pipe (open the grease pipe by probing as above). Select the proper grease cup, empty and clean out the grease cup (top and bottom). Install the bottom portion of the grease cup on the grease pipe.

5. Fill the bottom portion of the grease cup with clean grease, fill the top portion (cap) of the grease cup only half full of grease.

6. Thread the half filled cap of the grease cup onto the fully filled bottom of the grease cup and screw it down as far as it will go (by hand). Keep the machine running continuously while adding grease.

7. Repeat steps (5) and (6) above until clean grease begins to emerge from the drain hole.

8. Continue to run the machine and let grease run out of drain hole until drainage stops (normally about 30 minutes). Remove the grease cup and replace the pipe plug.

9. Replace the drain plug.

10. If a grease gun must be used, remove the drain plug in the bearing housing while greasing and use extreme care to avoid inserting too much grease or applying more than just enough pressure to get the grease into the housing.

High Temperature Grease

Bearings which normally operate at a temperature above 194° F (90° C) should be lubricated with a silicone grease in accordance with Military Specification MIL-L-15719A, Stock No. W9150-257-5358. Machines which require this special grease have a caution plate stating "USE HIGH TEMPERATURE GREASE" which is attached near the grease fitting by the manufacturer.

SLEEVE BEARINGS

A SLEEVE bearing is a type of sliding bearing employed in electric motors and generators. These bearings are used in large equipment, such as turbine-driven ship's service generators and propulsion generators and motors. The bearings may be made of bronze, babbitt, or steel-backed babbitt.

Preventive maintenance of sleeve bearings requires periodic inspections of bearing wear and lubrication.

Wear

Large motors and generators are usually provided with a gage for measuring bearing wear. Bearing wear on sleeve bearing machines not provided with a bearing gage can be obtained by measuring the air gap. It is usually not necessary to measure air gaps on machines which have ball bearings because the construction of the machine is such as to assure bearing alignment. Bearing wear of sufficient magnitude to be readily detectable by air gap measurements would be more than enough to cause unsatisfactory operation of ball bearings and would be detected in this way.

Air gaps on a sleeve bearing machine not provided with a bearing gage should be measured at each end of the machine. Air gaps can be measured with an air gap feeler. This is a machinist's feeler gage with a blade long enough to reach into the air gap without removing the end brackets of the machine. Before making the measurements, clean the varnish from a spot on a pole or tooth of the rotor. A spot should also be cleaned at the same relative position on each field pole of a d-c machine. For a-c machines, at least three and preferably four or more spots spaced at equal intervals around the circumference should be cleaned on the stator. The air gap measurements should be taken between the cleaned spot on the rotor and the cleaned spot on the stator, turning the rotor to bring the cleaned spots on the rotor opposite each of the cleaned spots on the stator.

If one end of the machine is accessible only with difficulty, either of the following procedures may be used:

1. Take several measurements at one end in accordance with the procedure described above, and two measurements approximately 90° apart at the less accessible end. If these two do not differ greatly from the mean of the measurements at the other end, the air gap is reasonably uniform at both ends.

2. Take several measurements at one end of the machine in accordance with the procedure described above, and average these to obtain the average air gap, or obtain the average air gap from records of preceding measurements. The average air gap is one-half the difference between the inside diameter of the stator (or field pole arrangement) and the outside diameter of the rotor (or armature), and is not affected by bearing wear. Procure a long, narrow strip of steel. The thickness of the steel strip should be 20 percent less than the average air gap for average air gaps smaller than 0.040 inch; it should be 10 percent less for average air gaps larger than 0.040 inch. Test the air gap by trying to push this strip all the way from one end of the air gap to the other. This test should be made at four points 90° apart, if possible, and if not, at a number of points (not less than three) spaced at approximately equal intervals around the circumference. The test can be repeated with a slightly thicker strip if a closer estimate is needed.

It is more important to have uniformity of air gaps at all points than to have the gap conform exactly to the specified limits. If the air gap at any of the places tested differs from the average air gap by more than 20 percent for average air gaps smaller than 0.040 inch, or by more than 10 percent for average air gaps larger than 0.040 inch, the bearings should be realigned, repaired, or replaced. Usually an inequality of air gaps which is not greater than specified above will not cause unsatisfactory operation. If, however, trouble is experienced, such as vibration or excessive noise which cannot be traced to any other cause than unequal air gaps, it is advisable to realign, repair, or replace bearings to equalize air gaps, even if the measured inequalities are within the limits given.

Lubrication

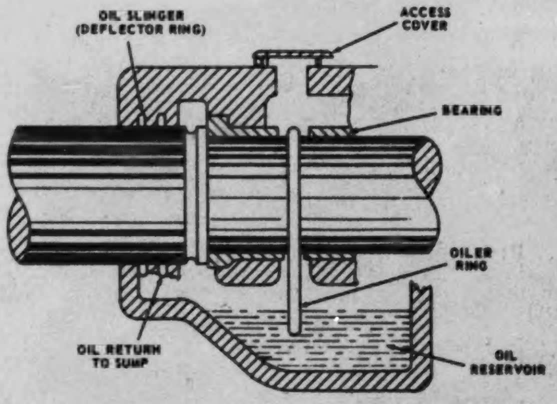
Every precaution should be taken to keep the oil and bearings clean and free from water or foreign particles.

Do not add oil while the machine is running. This affords an opportunity for oil mist or spray to escape from the bearing housing and be blown on the machine windings.

Bearings having an overflow gage should be filled until the oil is about one-sixteenth inch from the top of the gage. If the machine is equipped with an oil filter gage, the gage should be filled to the manufacturer's oil level mark, or (if no mark is available) the gage should be between two-thirds and three-quarters full at all times. Be sure that the gage glass and piping to the gage are clean or the glass will give false indications of the oil level. If the bearing has neither an overflow gage nor an oil filter gage, fill to a level so that the oil ring dips into oil to a depth of about half the shaft diameter.

When the bearing and bearing housing are in good condition, there should be no loss of oil. If the proper oil level cannot be maintained without adding oil, it is probable that oil is leaking from the bearing. Be sure the oil sight gage connection to the bearing is tight. Much of the oil that leaks out of a bearing is drawn into the machine by the cooling air and sprayed onto the windings where it causes oil soaked dirt to collect. This condition tends to cause insulation failure. If oil leakage is suspected, carefully clean and chalk the shaft outside the bearing, the outside of the bearing housing, and the parts of the rotor adjacent to the bearing. If the machine is throwing oil, discoloration of the chalk will so indicate after a short run. This test will not be dependable unless the chalked part is perfectly clean at the beginning of the test. If leakage is found, the labyrinth seal in the bearing housing should be corrected to make it effective. Another possible source of leakage is from the vent with which some labyrinths are provided. Made sure that any such vent is not stopped up and that it terminates in still air of atmospheric pressure where there is no current of air over the vent that will suck oil out of the bearing housing or oil vapor out of the vent into the machine. Such oil leakage is often due to overfilling the bearing or trying to fill the bearing through the vent.

Bearing oil should be renewed semiannually. Drain the oil off by removing the drain plug, then flush the bearing with clean oil until the drained oil flows clean.



77.239

Figure 7-54.—Diagram of an oil-ring lubricated bearing.

Oil Rings and Bearing Surfaces

An opening is provided in the top of the bearing for checking the condition of the oil rings and bearing surfaces (fig. 7-54). Periodic inspections are necessary to make certain that the oil ring is rotating freely when the machine is running. With the machine stopped, the bearing surfaces should be inspected for any signs of pitting or scoring.

Trouble Analysis

The earliest indication of sleeve bearing malfunction normally appears as an increase in the operating temperature of the bearing. This increase is due to the heat generated in the extremely sensitive oil film separating the rotating journal from the bearing surface and is governed by the slipping or shearing of the oil molecules. When the bearing is operating satisfactorily, the film temperature remains stable; but when the equilibrium of the oil film is interrupted, rapid and sharp changes occur in the temperature of the oil film. Oil is supplied under pressure from a central system to sleeve bearings in some large generators.

Thermometers are usually inserted in the discharge line from the bearing as a means of visually indicating the temperature of the oil as it leaves the bearing. Thermometer readings are taken hourly on running machinery by operating personnel. However, a large number of bearing casualties have occurred in which no temperature rise was detected in thermometer readings, and, in some cases, discharge oil temperature has actually decreased. Therefore, after checking the temperature at the thermometer, a followup check should be made by feeling the bearing housing whenever possible. Operating personnel must thoroughly familiarize themselves with the normal operating temperature of each bearing so that they will be able to recognize any sudden or sharp changes in bearing-oil temperature. Many large generators are provided with bearing temperature alarm contactors which are incorporated in the alarm system. The contactor is preset to provide an alarm when the bearing temperature exceeds a value detrimental to bearing life. If bearing malfunction is indicated, the affected machinery should be secured as soon as possible. A motor with overheated sleeve bearings should be unloaded, if possible, without stopping the motor. If stopped immediately, the bearing may seize. The best way to limit bearing damage is to keep the motor running at light load and supply plenty of cool, clean oil until the bearing cools down.

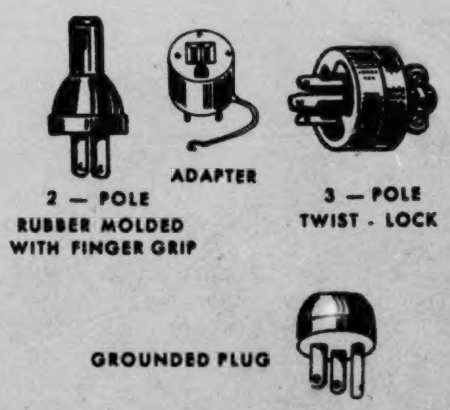
The temperature of sleeve bearings and the outer races of ball bearings should not be allowed to exceed the following values:

1. Sliding contact (sleeve) bearings — 82° C (180° F).

2. Rolling contact (ball) bearings on class A or B insulated motors — 90° C (194° F).

3. Rolling contact (ball) bearings on class H insulated motors — 150° C (300° F).

The permissible operating temperature is too high to be estimated by sense of touch. Temperature measurements are needed to determine whether a bearing is overheated. A thermometer securely fastened to the bearing cover or housing will usually give satisfactory measurements. A thermometer should not be inserted into a bearing housing; it may break and necessitate disassembly to remove glass and mercury.

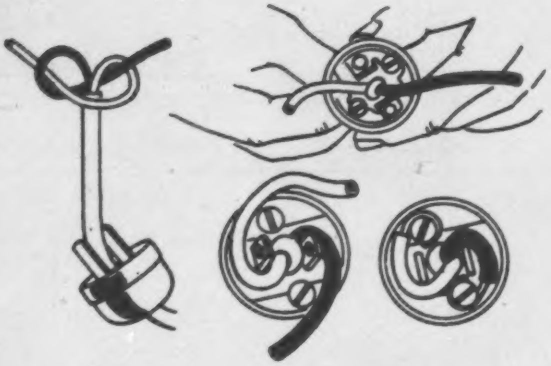


5.13A

Figure 7-55. — Attachment plugs.

Any unusual noise in operating machinery may also indicate bearing malfunction. Whenever a strange noise is heard in the vicinity of operating machinery, a thorough inspection must be made to determine its cause. Excessive vibration will occur in operating machinery with faulty bearings, and inspections should be made at frequent intervals in order to detect its presence as soon as possible.

Portable appliances and devices that are to be connected to receptacles have their electrical cords equipped with plugs (fig. 7-55) that have prongs which mate with the slots in the outlet receptacles. Equipment connected by a cord or plug should be grounded in accordance with the National Electric Code, article 250-45. A three-prong plug can fit into a two-prong receptacle by using an adapter. If the electrical conductors connected to the outlet have a ground system, the lug on the lead wire of the adapter is connected to the center screw holding the receptacle cover to the box. Many of these plugs are permanently molded to the attached cords. There are other types of cord-grips that hold the cord firmly to the plug. Twist-lock plugs have patented prongs that catch and are firmly held to a mating receptacle when the plugs are inserted into the receptacle slots and twisted. Where the plugs do not have cord-grips, the cords should be tied with an Underwriter's knot (fig. 7-56) at plug entry to eliminate tension on the terminal connections when the cord is connected and disconnected from the outlet receptacle.



5.13B

Figure 7-56.—The Underwriter's knot.

DOMESTIC OIL BURNERS, WINDOW AIR-CONDITIONERS, AND LARGE APPLIANCES

When you are assigned to "B" company or a Public Works electric shop, you will be involved with troubleshooting and repair of various types of heating units, window air-conditioners, and appliances. Your knowledge of wiring diagrams and schematics, along with a good understanding of locating grounds, shorts and opens in a circuit, will be of prime importance.

OIL BURNERS

The electrical portion of an oil burner in almost any type of automatic oil heating installation contains motors, relays, and thermostats. The sequence of operation will vary with the type and application of each oil burner. The manufacturer's manual will furnish you with this needed information. Examples of two types of operations follow.

Forced Hot-Water System

A thermostat senses the need for heat in the room and turns on the relay, closing the low-voltage circuit across the terminals of the relay (fig. 7-57). The relay, when turned on by the thermostat, starts the circulator and also energizes the stack switch. This closes the line-voltage circuit to the circulator and the low-voltage circuit across the terminals of the stack switch. The stack switch, when energized by either the relay or the operating immersion controls, starts the oil burner if the stack has cooled, returning the helix-operated contacts to the starting position. The oil burner runs until the thermostat is satisfied. The thermostat then turns off the relay which stops the circulator and simultaneously breaks the low-voltage circuit across the terminals of the stack switch, stopping the oil burner operation. When the operating immersion control used to maintain summer-winter (domestic hot water) senses the drop in the boiler water temperature, it energizes the stack switch as required. It breaks the low-voltage circuit across the relay terminals when the water temperature reaches its cutout setting. This operation does not affect the unit's hot-water circulator.

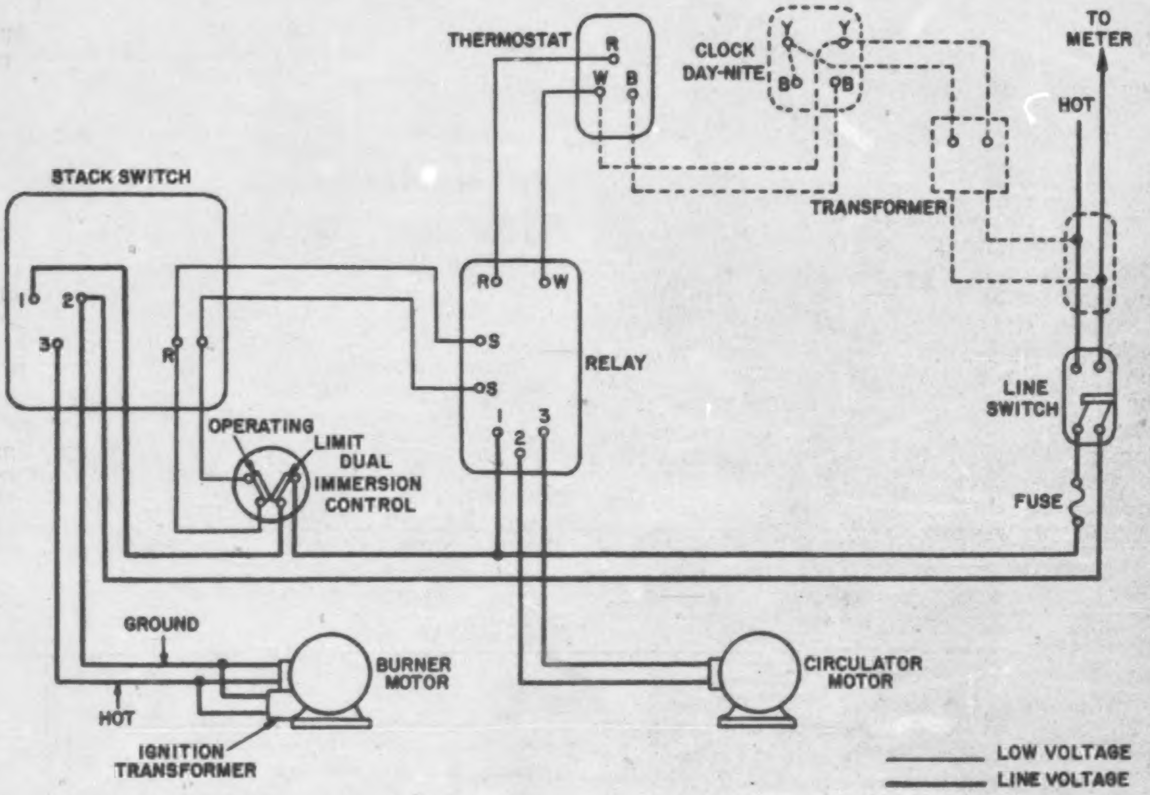
Forced Warm-Air System

A thermostat senses the need for heat in the room and energizes the stack switch which closes the low-voltage circuit across the terminals of the switch (fig. 7-58). When the stack switch is energized by the thermostat, it starts the oil burner, if the stack has cooled, returning the helix-operated contacts to the starting position. The oil burner runs until the thermostat is satisfied and turns off the stack switch, which opens the low-voltage circuits across the terminals to the stack switch or until the bonnet temperature reaches its present high point. This causes the safety limit control, which is part of the fan-and-limit control, to turn off the unit.

As soon as the combustion unit increases the bonnet temperature enough to ensure that warm air will be forced out of the residence registers, the fan side contacts of the fan-and-limit control starts the blower. The blower continues to function until the bonnet temperature is reduced to its cutoff setting.

There are basically three components in an oil burner ignition system:

1. The step-up high-voltage transformer which steps up from 115 volts line on the primary


THERMOSTAT
R
W
B
CLOCK
DAY-NITE
Y
Y
B
B
TO
METER
HOT
TRANSFORMER
STACK SWITCH
1
2
3
R
R
W
S
S
RELAY
1
2
3
LINE
SWITCH
OPERATING
LIMIT
DUAL
IMMERSION
CONTROL
FUSE
GROUND
BURNER
MOTOR
CIRCULATOR
MOTOR
HOT
IGNITION
TRANSFORMER
LOW VOLTAGE
LINE VOLTAGE

73.392

Figure 7-57.—Oil burner circuit, forced hot-water system.

side of approximately 10,000 volts on the secondary side.

2. Ignition wires or bus bars which are a point of contact for the high-voltage source to reach the electrode assembly.

3. The electrode assembly which consists of a combination of insulated porcelain and steel electrodes for spark which is used for ignition.

This system provides the spark or lightoff required to ignite the fuel oil as it enters the combustion chamber. The spark must be correctly positioned to provide immediate ignition to the prepared fuel. It cannot be delayed, weak, or off-target. These and other defective conditions can result in odor, dirt, inconvenience, and possible hazard. Some units are designed so that the spark remains on for just a short period after providing initial ignition or lightoff. In other types of systems, the spark remains on during the entire firing cycle.

This spark occurs on the tips of the two properly positioned electrodes, and the high-voltage transformer provides the electricity to produce it. It must be strong enough to bridge the correctly set gap between the electrodes. Setting the electrode gaps will vary with each unit. Manufacturer's instructions will be provided for each burner.

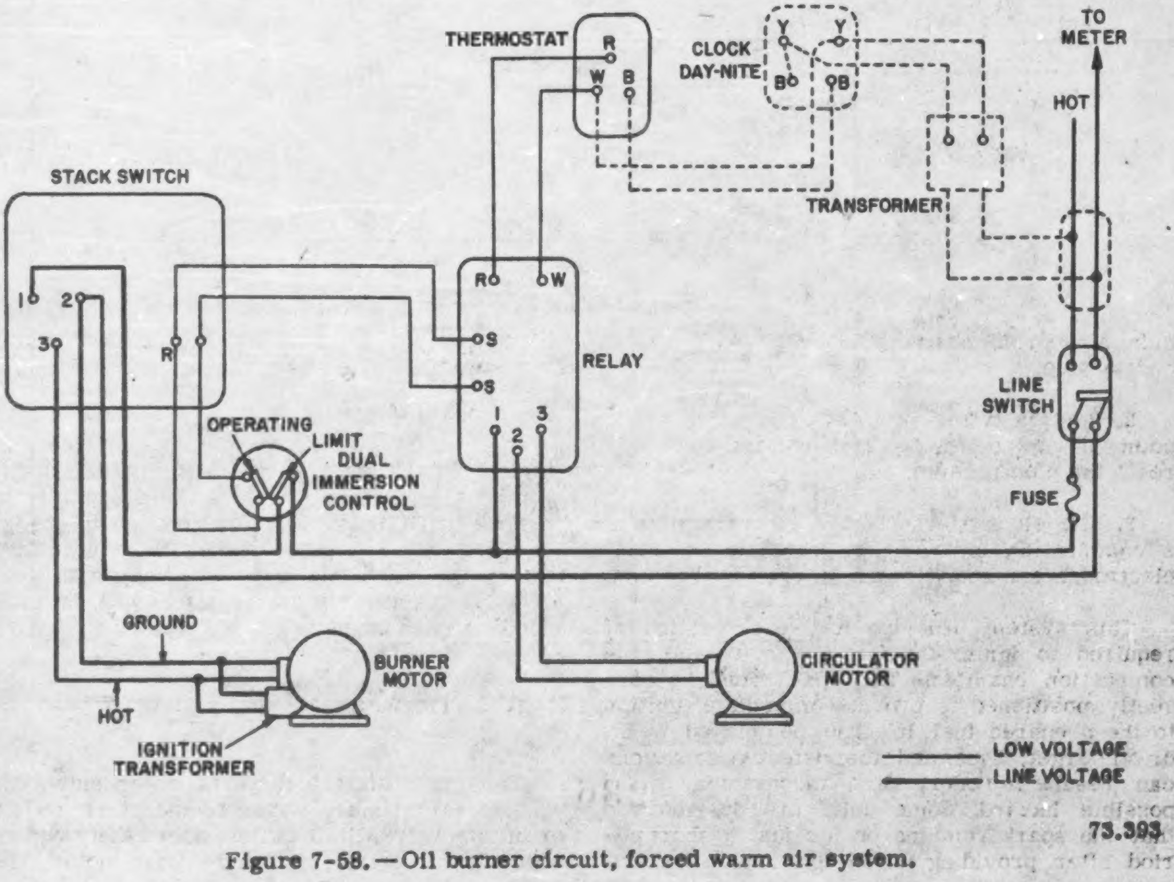
AUTOMATIC WASHERS

The main electrical parts of an automatic washer are: timer, water temperature switch or mixing valve, limit switch, door safety switch, water level control, and main drive motor. The timer is the most involved of all these parts. Figure 7-59 shows a wiring diagram of the electrical parts controlled by the timing device.

The time cycle in figure 7-60 is for a typical top load washer. The sequence of operation for the regular cycle is as follows: The fill cycle turns on the mixing valves. The machine fills with water until the timer advances to wash. The wash cycle starts the two-speed motor on low and works the agitator until the cycle is complete. There is a pause between the wash and spin rinse cycle. The spin rinse turns the motor on high speed and a clutch device engages the water pump to spin out the wash water. Fresh water is also sprayed into the machine during this cycle. The machine stops at the end of the spin cycle and fills again. The entire process is then repeated except for rinsing instead of washing. There will be variations depending on the manufacturer. The final spin uses no water, so the clothes will come out damp dry.

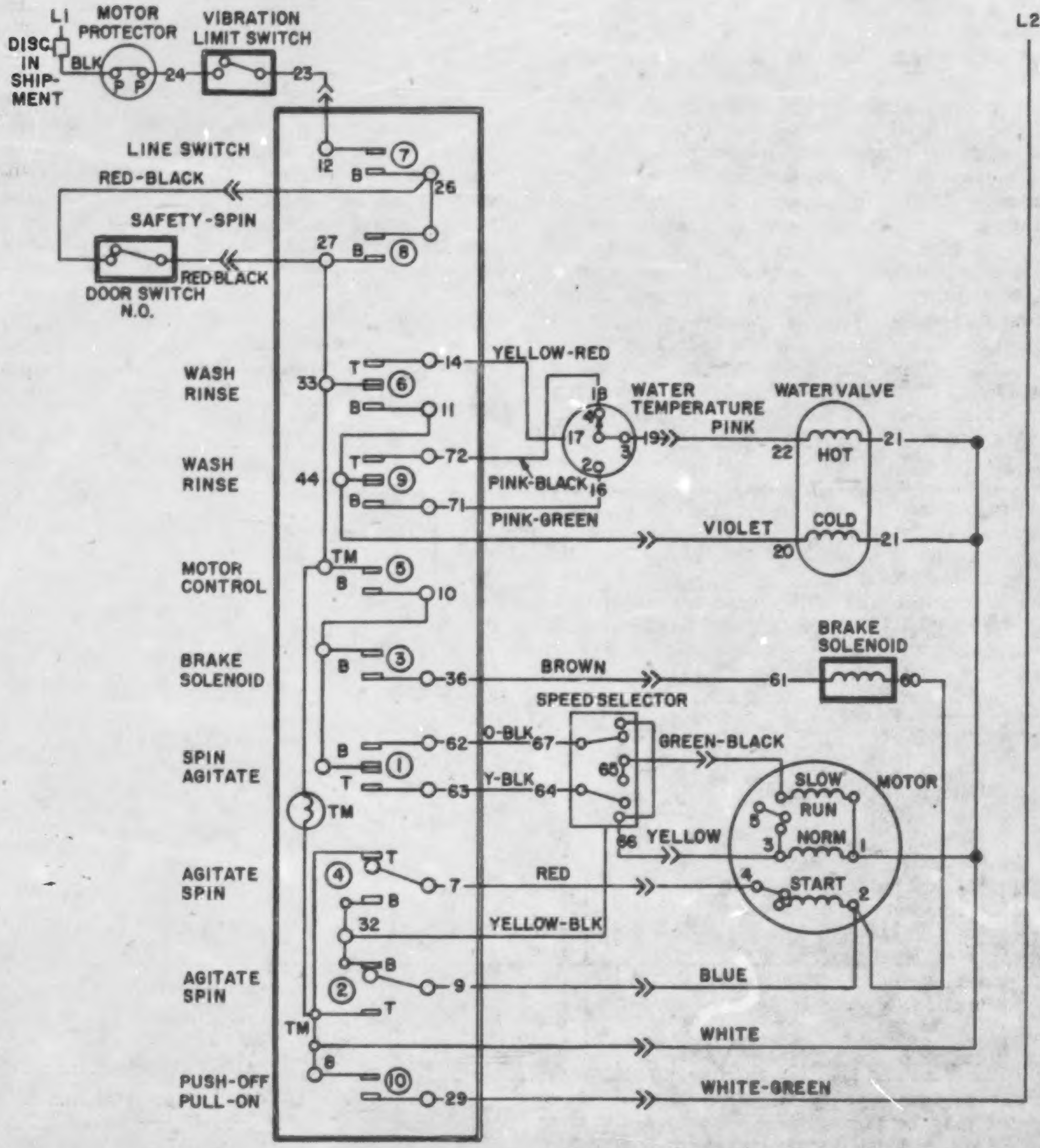
ELECTRIC DRYERS

The main electrical parts of a dryer are: electric heating elements, thermostats to control heat, a motor to turn the main drum assembly, and a timer to select cycle operations. Most dryers have a cutoff switch on the door which stops the dryer when the door is opened. Many dryers have a 40-watt ozone bulb to help condition the air. This bulb requires either a ballast coil or a ballast bulb. Both high-limit and low-limit operating thermostats are used in dryers to control the air temperatures that pass through the clothes. These are located in


THERMOSTAT
R
W
B
CLOCK
DAY-NITE
Y
Y
B
B
TO METER
HOT
TRANSFORMER
STACK SWITCH
1
2
3
R
R
W
S
S
RELAY
1
2
3
OPERATING
LIMIT
DUAL
IMMERSION
CONTROL
LINE SWITCH
FUSE
GROUND
BURNER MOTOR
HOT
IGNITION TRANSFORMER
CIRCULATOR MOTOR
LOW VOLTAGE
LINE VOLTAGE

73.393

Figure 7-58.—Oil burner circuit, forced warm air system.


L1
MOTOR PROTECTOR
VIBRATION LIMIT SWITCH
L2
DISC. IN SHIPMENT
BLK
P P
24
23
LINE SWITCH
12
7
B
RED-BLACK
26
SAFETY-SPIN
27
B
8
RED-BLACK
DOOR SWITCH N.O.
WASH RINSE
33
T
14
YELLOW-RED
6
B
11
18
WATER TEMPERATURE
PINK
WATER VALVE
4
17
19
3
2
16
22
HOT
21
WASH RINSE
44
T
72
9
B
71
PINK-BLACK
PINK-GREEN
VIOLET
COLD
20
21
MOTOR CONTROL
TM
5
B
10
BRAKE SOLENOID
B
3
36
BROWN
61
60
BRAKE SOLENOID
SPEED SELECTOR
SPIN AGITATE
B
62
O-BLK
67
GREEN-BLACK
1
65
T
63
Y-BLK
64
SLOW
MOTOR
RUN
5
TM
66
YELLOW
3
NORM
1
AGITATE SPIN
4
T
7
RED
4
START
2
B
32
YELLOW-BLK
AGITATE SPIN
B
2
9
BLUE
T
TM
WHITE
8
PUSH-OFF PULL-ON
10
29
WHITE-GREEN

73.394

Figure 7-59. — Wiring diagram showing electrical connections from timer to other electrical parts.

REGULAR CYCLE	TIME(MIN)	GENTLE CYCLE	TIME(MIN)
FILL	4	FILL	4
WASH	2-10	WASH	3
PAUSE	1	PAUSE	1
SPIN	2	SPIN	2
SPIN SPRAY	1	SPIN SPRAY	1
FILL	3	FILL	3
OVERFLOW RINSE	4	OVERFLOW RINSE	1
DEEPWAVE RINSE	1	DEEP WAVE RINSE	1
PAUSE	1	PAUSE	1
SPIN	1	SPIN	3
SPIN SPRAY	1		
SPIN	5		
TOTAL	34 MIN.	TOTAL	20 MIN.

73.395

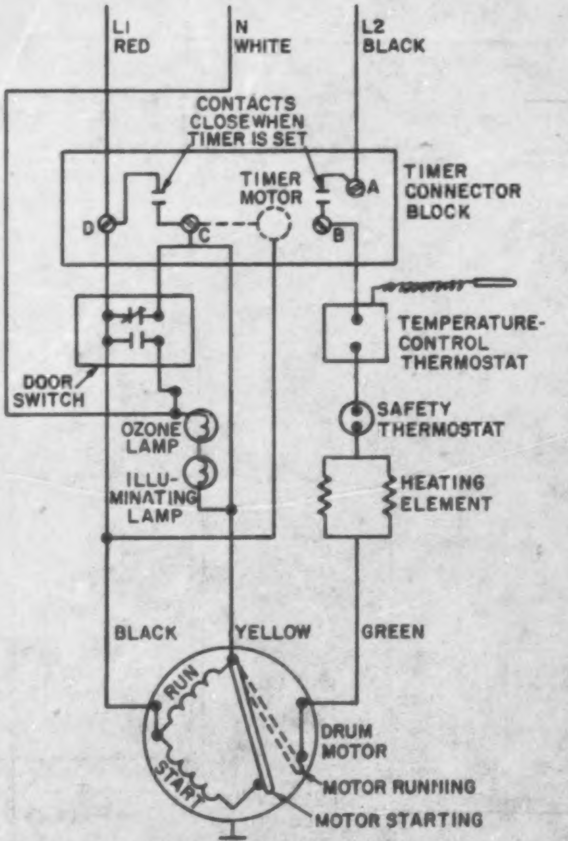
Figure 7-60.—Time cycle for an automatic washer.

the exhaust housing and can be easily checked during operation by a voltage check. The tester will indicate a voltage each time the contact is opened. Safety thermostats should show continuity between terminals at normal room temperature. Holding a small flame close under it should cause it to open, indicating an open circuit across its contacts. Dryer timers are fairly simple to troubleshoot. Some timer drive motors and switching mechanisms can be replaced, but in most cases it is more practical to replace the timer. Figure 7-61 is a wiring diagram for an electric dryer.

ELECTRIC HOT-WATER HEATERS

An electric hot-water heater is a metal water-storage tank with one or two electric heating elements, thermostatically controlled to heat water in the tank. It is a simple device and among electrical problems that may arise are: no power, defective thermostat, thermostat out of calibration, or defective heater element.

The hookup of a hot-water heater will vary with the size and application of each unit. Where power consumption is a problem, a hot-water heater may be placed on a timeclock and taken out of the system during maximum power consumption periods (fig. 7-62). Most units at advanced bases will be hooked up without a timing device as shown in figure 7-63. The thermostats in the figure operate as follows: The single-throw thermostat is in series with the heating element and has only one set of contacts, which open and close in response to the temperature at the bottom of the water-heater tank. The double-throw thermostat controls both the upper and lower heating elements. The switch closes the circuit in the upper heating unit whenever the water temperature in the top of the tank becomes lower than the thermostatic switch setting. When the top part of the tank reaches a preset temperature, the switch opens the contacts to the upper unit and, by a toggle action, closes the contacts to the lower unit. The lower unit comes on and remains on until its preset thermostat is satisfied.


L1
RED
N
WHITE
L2
BLACK
CONTACTS
CLOSE WHEN
TIMER IS SET
TIMER
MOTOR
A
D
C
B
TIMER
CONNECTOR
BLOCK
TEMPERATURE-
CONTROL
THERMOSTAT
DOOR
SWITCH
SAFETY
THERMOSTAT
OZONE
LAMP
ILLU-
MINATING
LAMP
HEATING
ELEMENT
BLACK
YELLOW
GREEN
RUN
START
DRUM
MOTOR
MOTOR RUNNING
MOTOR STARTING

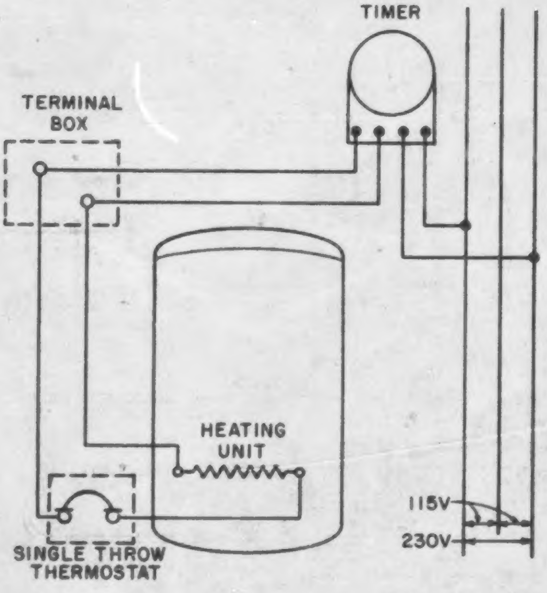
73.396

Figure 7-61.—Schematic of an automatic dryer.

RANGES

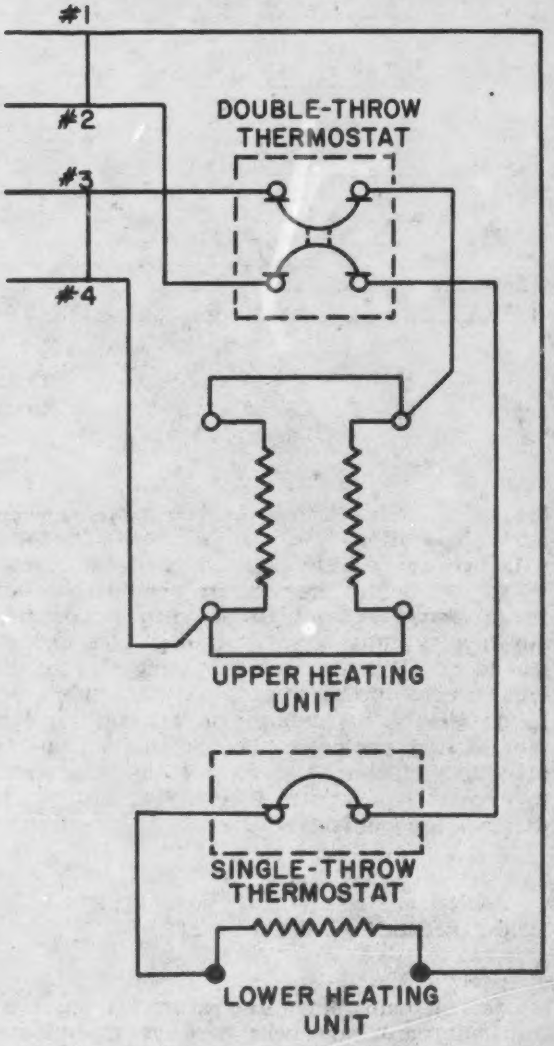
The electric ranges you will be working on wil vary in size and style but will all basically work the same. Surface heating elements work off a selector switch which changes the voltage and resistance value of the element, giving you a variety of heating temperatures. Figure 7-64 shows how this is accomplished. Oven elements work off a thermostat to control heat temperature and a timing device for automatic shutoff as shown in figure 7-65.

In troubleshooting, start by checking to ensure proper voltage to the unit, then checking out each element and control device. The heating element, though ruggedly constructed, might become open-circuited. This can be checked out with an ohmmeter. Normal resistance is somewhat less than 100 ohms. If elements are opened, replacement is necessary. If the heating element checks normal, but the unit doesn't heat up, the controls should then be checked. Voltage measurement is the most reliable test for a switch. When turned off, the measurement across the switch terminals should read full line voltage, 120 or 240 volts. When the switch is on, the reading should be zero across the terminals. Any voltage reading across the terminal of a closed switch indicates a fault. Replacing a faulty switch involves the disconnection and reattachment of many wires. A sketch or identifying tags should be used to ensure the correct relocation of



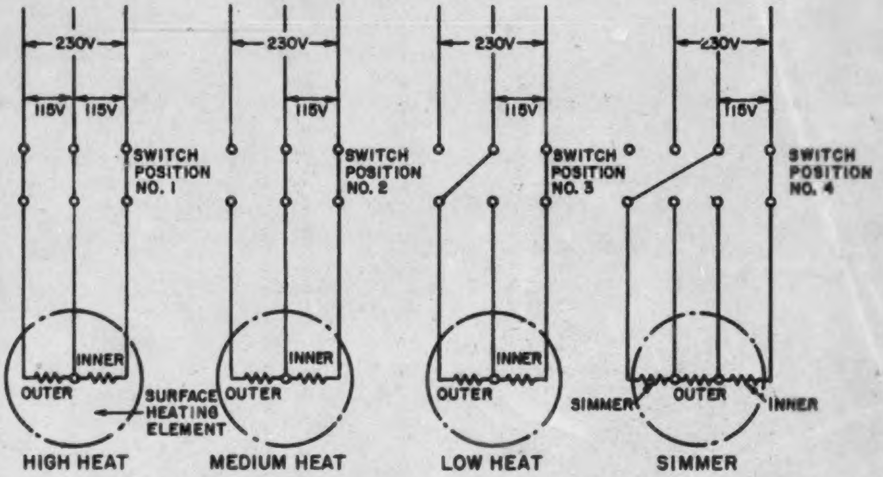
73.397

Figure 7-62.—Wiring diagram for a limited-demand, time-controlled, hot-water heater.



73.398

Figure 7-63.—Wiring connections for an electric water heater having two heating units.


230V
230V
230V
230V
115V
115V
115V
115V
115V
SWITCH POSITION NO. 1
SWITCH POSITION NO. 2
SWITCH POSITION NO. 3
SWITCH POSITION NO. 4
INNER
OUTER
SURFACE HEATING ELEMENT
INNER
OUTER
INNER
OUTER
SIMMER
OUTER
INNER
HIGH HEAT
MEDIUM HEAT
LOW HEAT
SIMMER

73.399

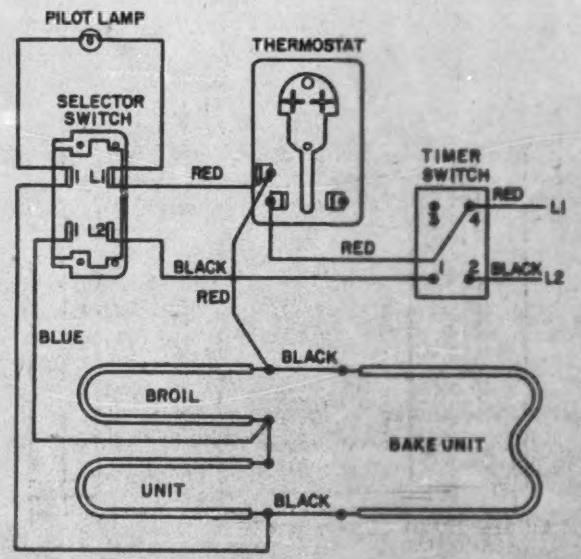
Figure 7-64.—Surface heating element with four-heat switching.

wires. Oven thermostats control temperature and are factory calibrated for that unit. Some units can be recalibrated but most must be replaced. When replacement is necessary the exact type is preferred; however, universal type replacements are available. The manufacturer's instructions that come with a thermostat will give you the exact method for installing and calibrating the device.

Faulty wiring is the final check. Unless arcing damage is evident, test a wire by disconnecting both ends from the circuit; then check it with an ohmmeter. A good wire checks 0 ohms; a faulty one, infinity (∞). Replacement of a faulty conductor should be made with asbestos-covered heater wire. Solder is not used because it will melt; spade-tongue or quick-connect terminals are used instead.

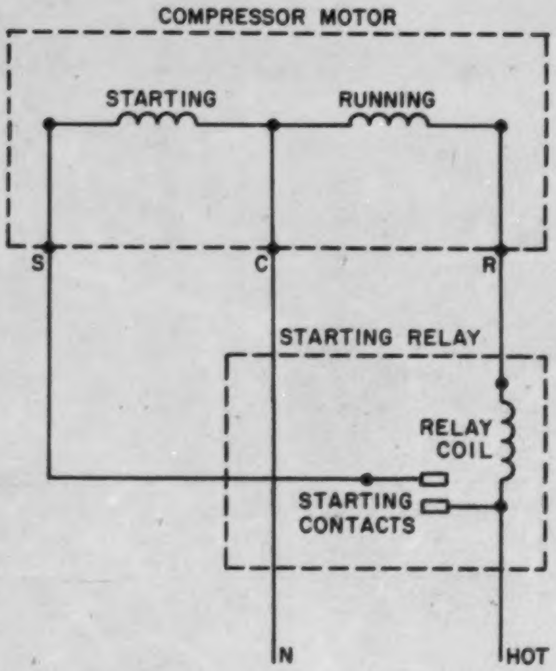
HERMETIC COMPRESSOR APPLICATION

Hermetic compressors contain the motor and compressor in a sealed unit. The motor and compressor work off the same shaft; therefore, no shaft seal or belt drive is required. This arrangement provides a more compact assembly and takes up less space.


PILOT LAMP
THERMOSTAT
SELECTOR SWITCH
L1
L2
RED
TIMER SWITCH
RED
L1
RED
BLACK
BLACK
L2
RED
BLUE
BLACK
BROIL
BAKE UNIT
UNIT
BLACK

73.400

Figure 7-65.—Oven heating circuit with two heating units.



73.401
Figure 7-66.—Schematic wiring of a compressor-motor and starting relay.

Almost all household refrigerators, window air-conditioners, and ice cube machines you will be working on have hermetic compressors.

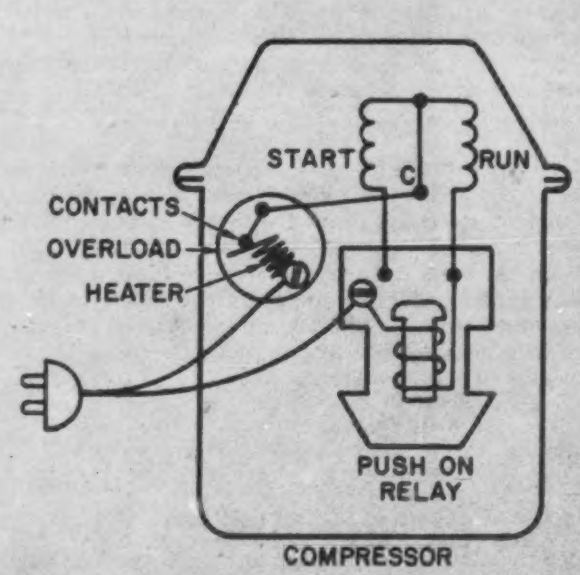
Compressor motor sizes will vary, depending on application and capacity of the system. The compressor motor consists of a starting and running winding. The running winding is energized during the complete cycle period, whereas the starting winding is energized only during the starting period, because additional starting torque is required in single-phase units.

STARTING RELAYS are used at the moment of starting. (figure 7-66). When the electrical circuit is completed by a control device calling for the system to operate, current passes through the starting relay coil and running winding. The high current drawn by the running winding causes the starting relay coil to close its contacts. The current passing through the starting coil induces an out-of-phase, magnetic field in the stator and starts the motor. As the motor speed increases, the current in the running winding is reduced. This drops the value of the current in the starting relay and opens its contacts, taking the starting winding out of the circuit. The motor continues to run on the running winding as an induction motor.

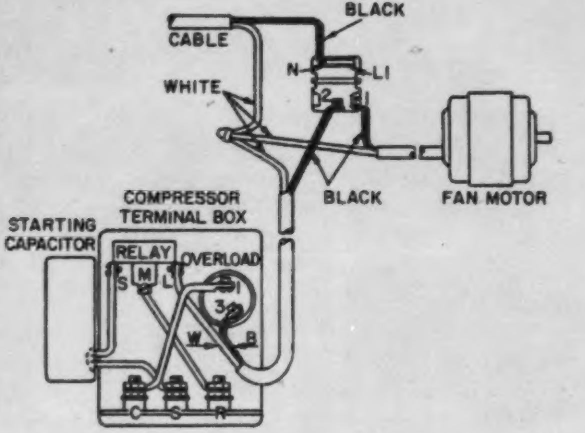
OVERLOAD PROTECTION is provided by a bimetallic strip in series with the compressor windings (fig. 7-67). Should the current in the motor windings increase to a dangerous value, the heat developed by the current passing through the bimetallic overload will cause its contacts to open circuit. This will stop the motor before any danger occurs. When the bimetallic strip cools, it will return the contact to the closed position.

WINDOW AIR-CONDITIONERS

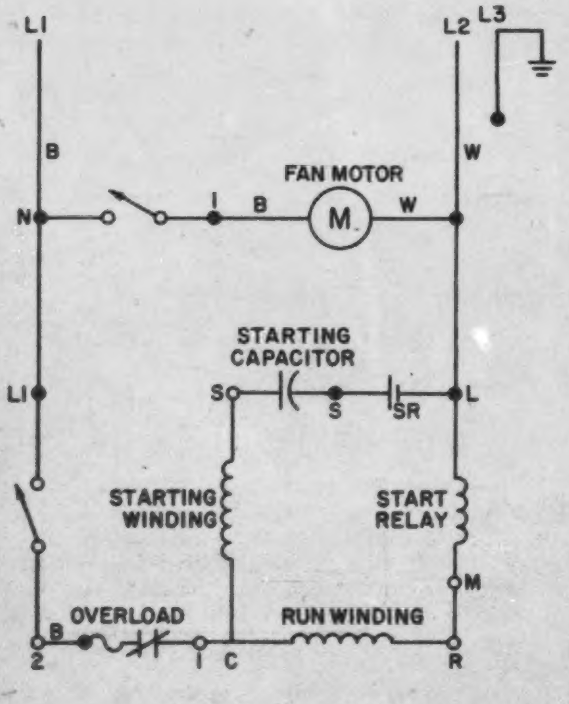
A basic electrical system for a window air-conditioner consists of a hermetic compressor



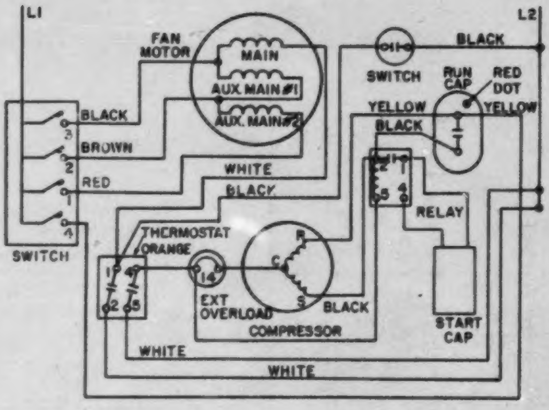
73.402
Figure 7-67.—Wiring diagram of a compressor-motor with overload protection.


BLACK
CABLE
WHITE
N
L1
2
1
BLACK
FAN MOTOR
COMPRESSOR TERMINAL BOX
STARTING CAPACITOR
RELAY
S
M
L
OVERLOAD
1
3
W
B
C
S
R

73.403
Figure 7-68.—Air-conditioner diagram with one fan motor and hermetic compressor.


L1
L2
L3
B
W
FAN MOTOR
N
I
B
M
W
STARTING CAPACITOR
L1
S
S
SR
L
STARTING WINDING
START RELAY
M
OVERLOAD
RUN WINDING
B
2
I
C
R

73.404
Figure 7-69.—Schematic wiring diagram of the air-conditioner in figure 7-68.


L1
L2
FAN MOTOR
MAIN
AUX. MAIN #1
AUX. MAIN #2
SWITCH
BLACK
RUN CAP
RED DOT
YELLOW
YELLOW
BLACK
BLACK
3
BROWN
2
RED
1
4
WHITE
BLACK
SWITCH
RELAY
THERMOSTAT ORANGE
EXT OVERLOAD
C
R
S
BLACK
COMPRESSOR
START CAP
WHITE
WHITE

SWITCH POSITION	CONTACTS CLOSED
OFF	NONE
FAN	L1 TO 2
HI-COOL	L1 TO 3 & 4
MED-COOL	L1 TO 2 & 4
LO-COOL	L1 TO 1 & 4

73.405
Figure 7-70.—Window air-conditioner with starting and running capacitors.

with thermal overload protection, starting relay, starting capacitors, running capacitor (on some models), motor thermostat, and unit control switch (on-off and fan speed). Hermetic compressors, thermal overloads, and starting relays have been previously discussed.

The choice of starting or running capacitors of air-conditioners depends on the type and size of unit. The thermostat or temperature control stops and starts the compressor in response to room temperature. Its principle of operation will be discussed later in this chapter.

In studying figures 7-68 and 7-69, you will notice a starting capacitor is used. These capacitors are of the electrolytic type and are used in motor starting windings to effect an increase in starting torque. Starting capacitors are intended for short and infrequent compressor

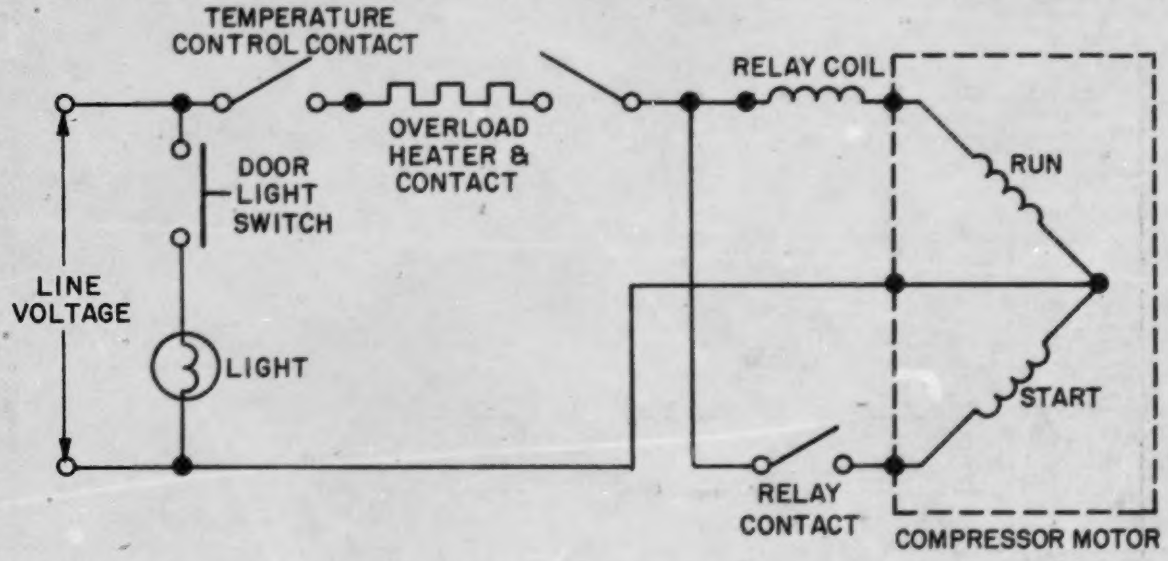
TROUBLE	POSSIBLE CAUSE	POSSIBLE REMEDY
UNIT WILL NOT RUN	BLOWN FUSE	CHECK FOR AN ELECTRICAL SHORT AT WALL RECEPTACLE. REPLACE FUSE.
	BROKEN OR LOOSE WIRING	
	LOW VOLTAGE	CHECK VOLTAGE. VOLTAGE SHOULD BE WITHIN 10% OF THAT SHOWN ON THE UNIT NAMEPLATE.
	DEFECTIVE UNIT STARTING SWITCH	CHECK VOLTAGE AT SWITCH. IF THERE IS PROPER VOLTAGE AT SWITCH, BUT NO CONTINUITY THROUGH IT, REPLACE SWITCH.
FAN RUNS, BUT COMPRESSOR WILL NOT OPERATE	INOPERATIVE THERMOSTAT	IF TURNING THERMOSTAT TO ITS COLDEST SETTING DOES NOT START COMPRESSOR (AND ROOM TEMPERATURE IS ABOVE 75°), BUT SHORTING ACROSS ITS TERMINALS DOES, CHANGE THERMOSTAT.
	LOOSE OR BROKEN WIRING	CHECK UNIT WIRING AND WIRING CONNECTIONS AT THE UNIT STARTING SWITCH AND AT THE COMPRESSOR.
	STARTING CAPACITOR FAULTY (IF USED)	CHECK STARTING CAPACITOR (IF USED).
	RUNNING CAPACITOR FAULTY	CHECK RUNNING CAPACITOR.
	RELAY FAULTY (IF USED)	CHECK RELAY (IF USED).
	OFF ON OVERLOAD OR OVERLOAD FAULT	CHECK FOR OVERHEATED COMPRESSOR OR FOR DEFECTIVE OVERLOAD.
	LOW VOLTAGE	CHECK VOLTAGE.
UNIT BLOWS FUSES	SHORTED OR INCORRECT UNIT WIRING	CHECK UNIT WIRING.
	SHORTED STARTING OR RUNNING CAPACITOR	CHECK CAPACITORS.
	SHORTED OR STUCK COMPRESSOR	CHECK COMPRESSOR.
	COMPRESSOR STARTING DIFFICULTY	CHECK FOR LOW VOLTAGE. CHECK STARTING CAPACITOR AND RELAY.
	INCORRECT FUSE	CHECK FUSE SIZE.

73.406

Figure 7-71.—Troubleshooting chart for window air-conditioner.

starts. Any operating fault that would cause a starting capacitor to remain in the circuit for more than several seconds could cause its failure. Internally shorted capacitors will cause starting trouble and blown fuses; with open-circuited starting capacitors, the compressor may not run. Running capacitors are used in some systems. They are heavy-duty, oil-filled capacitors that can remain in the circuit continuously. Running capacitors also increase starting torque and reduce the running amperage by increasing the power factor.

Fan motors are usually of two types: split-phase capacitor motor or shaded-pole motor. The number of fan motor leads will vary, depending on the type of motor used. Shaded-pole motors will have either two or three leads, depending on whether the speed winding is incorporated in the motor, or if a reactor is used to reduce the fan speed. Figure 7-70 shows a circuit with starting and running capacitors. The fan motor speed is controlled by the motor windings. The unit control switch may be a rotating control dial or pushbutton type, depending on the



73.407

Figure 7-72.—Basic refrigerator wiring diagram.

manufacturer. Switching positions such as those shown in figure 7-70 are given in the manufacturer's instructions. Knowing the switch position makes troubleshooting the system easier.

Troubleshooting charts can be found in most manufacturer's manuals. These charts are intended to provide quick reference to the cause and correction of a specific fault (fig. 7-71).

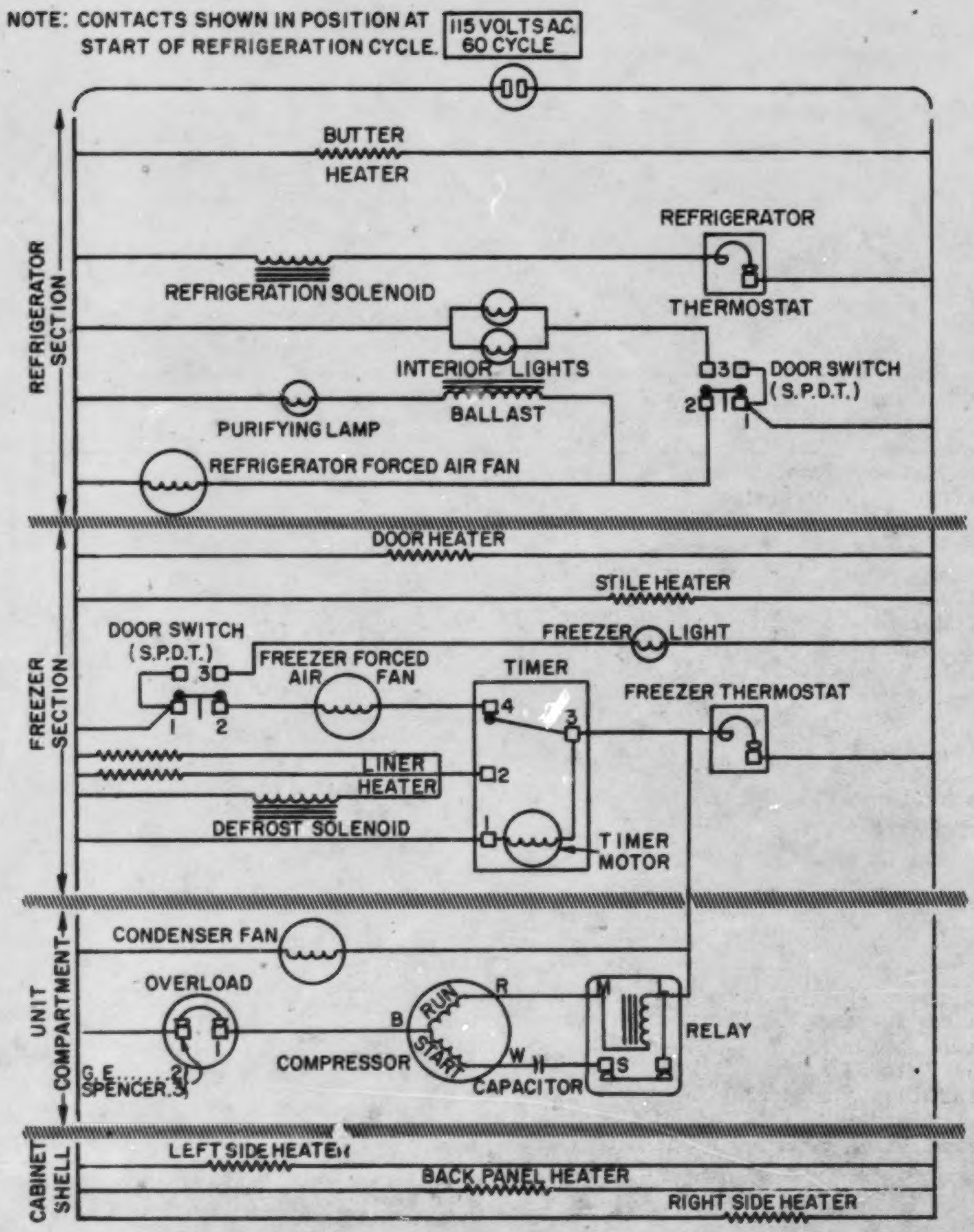
HOUSEHOLD REFRIGERATORS

The electrical wiring of household refrigerators may differ considerably from unit to unit, depending on compressor protection, method of defrosting, and extra design features. The simplest form consists of a motor-compressor, light switch, and temperature control (fig. 7-72).

The temperature control or thermostatic switch operates on the expansion and contraction of a gas-filled bulb. As the temperature in the box rises, the gas expands, closing the contacts on a toggle switch. The hermetic compression comes on and the refrigeration cycle begins. When the box temperature drops to a preselected temperature, the thermostat opens, stopping the compressor.

Other refrigerators have automatic defrosting, internal forced-air fans, and panel heating elements. The automatic defrosting can be accomplished by several different methods, depending on the manufacturer. One method is shown in figure 7-73. The electric timer clock is preset to defrost the system every 12 hours. During this period the freezer fan motor is stopped and the heaters placed around the cooling coils are energized. This cycle lasts about 10 to 18 minutes, depending on the size of the unit. Most refrigerators have the wiring diagram on the back of the unit. You should study it before troubleshooting the electrical system.

Learning the sequence of operation of both the mechanical and electrical components (such as the defrost timing device) will save you time and needless disassembly of internal components, such as heaters placed around cooling coils. Take a few minutes to study each job; it will save time in the long run. Troubleshooting guides in the manufacturer's manual are a big help. The more you work on a system, the easier it will become to recognize possible causes of trouble.


NOTE: CONTACTS SHOWN IN POSITION AT START OF REFRIGERATION CYCLE.
115 VOLTS A.C. 60 CYCLE
BUTTER HEATER
REFRIGERATOR THERMOSTAT
REFRIGERATION SOLENOID
INTERIOR LIGHTS
DOOR SWITCH (S.P.D.T.)
BALLAST
PURIFYING LAMP
REFRIGERATOR FORCED AIR FAN
REFRIGERATOR SECTION
DOOR HEATER
STILE HEATER
FREEZER LIGHT
DOOR SWITCH (S.P.D.T.)
FREEZER FORCED AIR FAN
TIMER
FREEZER THERMOSTAT
LINER HEATER
DEFROST SOLENOID
TIMER MOTOR
FREEZER SECTION
CONDENSER FAN
OVERLOAD
RUN
START
R
B
W
M
L
S
COMPRESSOR
CAPACITOR
RELAY
G.E.......2
SPENCER.3
UNIT COMPARTMENT
LEFT SIDE HEATER
BACK PANEL HEATER
RIGHT SIDE HEATER
CABINET SHELL

73.408

Figure 7-73.—Diagram of refrigerator-freezer with automatic defrost.

CHAPTER 8

INTERIOR WIRING

At any Navy base, the electrical system consists of three parts: the power plant that supplies the electrical power, the distribution system that carries the electrical current from the generating station to the various buildings, and the interior wiring systems that feed the electrical power to the appliances and equipment within a building.

As defined here, interior wiring begins at the point where the distribution systems service leads are connected to the wiring from within the building and extends through each circuit of the building's interior wiring to the last fixture installation.

The interior wiring system must meet two essential requirements: it must be safe for personnel and the appliances it serves, and, further, must be capable of serving these appliances properly for as long as necessary.

In this chapter, we will discuss your responsibilities in meeting various code and specification requirements and a variety of techniques for installing, repairing and maintaining interior wiring.

SPECIFICATIONS AND REQUIREMENTS

All Navy electrical installations ashore must conform to rigid standards and specifications. As a CE, you must be aware of the requirements set by three sources: the Federal Government, which puts out military standards and specifications (MIL-STD's and MIL-SPEC's); the Naval Facilities Engineering Command (NAVFAC), which writes NAVFAC specifications; and the National Fire Protection Association, which prepares and publishes the National Electrical Code.

MILITARY STANDARDS AND SPECIFICATIONS

Although various industry and government agencies have developed many specifications and standards, the military has established its own MILITARY STANDARDS (MIL-STD's) and MILITARY SPECIFICATIONS (MIL-SPEC's). In many cases, these requirements are more rigid than their civilian counterparts, so that components can withstand the test of severe environmental and usage conditions.

NAVFAC SPECIFICATIONS

CE's are also required to follow the specifications issued by the Naval Facilities Engineering Command (NAVFAC) when performing any work involving electrical apparatus, distributing systems, and wiring. NAVFAC specifications, however, are all-inclusive and advise you of those specifications (MIL-STD, federal, or commercial) you must use for particular applications.

Remember that specifications, whether military or civilian, are updated periodically and you must check to see that you use the most current ones.

NATIONAL ELECTRICAL CODE

The NATIONAL ELECTRICAL CODE (NEC) is prepared and published every 3 years by the National Fire Protection Association. Its purpose is to safeguard personnel and buildings and their contents from hazards arising from the use of electricity.

How does this code minimize the dangers mentioned above? Briefly, the NEC provides:

- various methods of wiring and descriptions of materials,
- techniques for wiring design and protection,
- requirements of general and special equipment,

- special conditions and occupancy information, and
- a variety of tables and examples for calculations.

This wealth of information provides Construction Electricians with a strictly-to-be-observed guide that experience has shown will minimize electrical hazards to personnel and buildings. Study the NEC closely and learn it well. It will prove useful to you throughout your career as a Construction Electrician. As you advance in rate, you may be required to teach courses on its contents.

INTERIOR WIRING MATERIALS

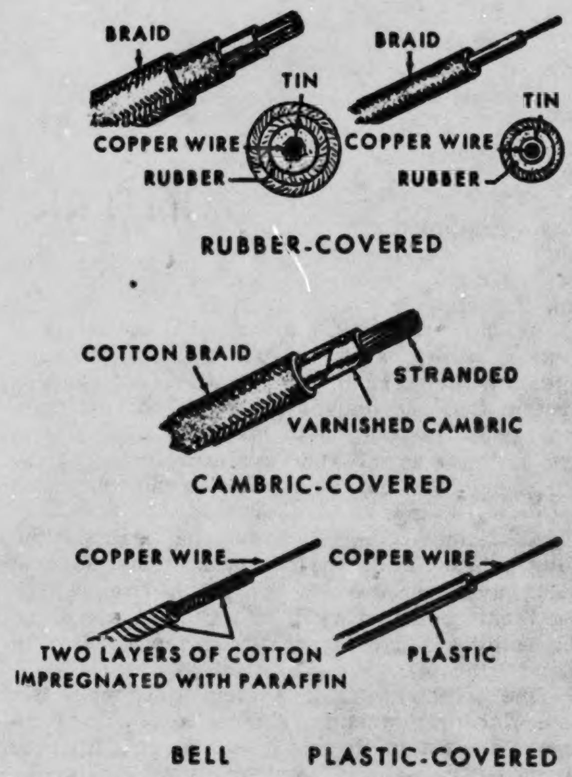
Every wiring job calls for its own particular type of material. Whether to use rigid, flexible, or thin-wall conduit might be a decision you will have to make. Use the information provided here to become familiar with installation requirements. Learn to use the proper cable, conductors, and conduit in the correct place. Make sure you are familiar with methods of bending, joining, and installing the various materials; and learn to select the proper fittings and accessories that you will need in installing materials. As you are referred to the NEC throughout this discussion, look up the articles indicated and get acquainted with the NEC book. It will be your guide on acceptable and safe procedures. A good Construction Electrician takes pride in doing a neat, safe and proper job.

CONDUCTORS

Electrical conductors generally consist of drawn copper or aluminum formed into a wire. They provide paths for the flow of electric current and usually have insulating material (fig. 8-1) encasing the metal. The insulation material is provided to minimize short circuits and to protect personnel. Atmospheric conditions, voltage requirements, and environmental and operating temperatures are factors considered in the selection of the type of insulating material for a particular job.

Single Conductors

A conductor may consist of a single solid wire or combination of a number of solid wires (stranded) which are not insulated from each other and share in carrying the total current.



73.301

Figure 8-1.—Single conductors.

Stranded conductor has the advantage of being more flexible than solid conductor, making it more adaptable for pulling through bends in conduit.

Conductors vary in diameter. Wire manufacturers have established a numerical system called the American Wire Gage (AWG) standard. Table 8 of the NEC and page 127 of Basic Electricity, NAVPERS 10086-B, show how this numerical system eliminates the necessity for cumbersome circular mil or fractional inch diameters when describing wire sizes. Notice that the wire gage numbers increase from 1 through 18 as the diameter of the wire decreases.

Size, Number, and Ampacity

The wire size most frequently used for interior wiring is No. 12 AWG, used as a solid copper conductor. Table 310-17, column 2, of the NEC shows the allowable ampacity of a single conductor in free air, No. 12 AWG (for types RUW, T, and TW insulation) to be 25 amperes. However, the minute that conductor is not alone in free air, and is placed in a raceway, cable or direct burial, you can see, by referring to Table 310-16, that its ampacity is reduced to 20 amperes, provided that not more than three conductors are in the raceway or cable. What happens if more than three conductors are in the raceway conduit, or cable? The following information indicates the reduced ampacities for a variety of numbers of conductors in such a situation.

Number of conductors	Percent of normal current-carrying capacity
4 to 6	80
7 to 24	70
25 to 42	60
43 and over	50

Suppose, now, that you have four to six No. 12 wires in a conduit. The allowable current-carrying capacity would be only 80 percent of normal, or 16 amps. To ensure a current-carrying capacity of 20 amps, you would have to use No. 10 wire, which has a normal current-capacity of 30 amps, 80 percent of which is 24 amps.

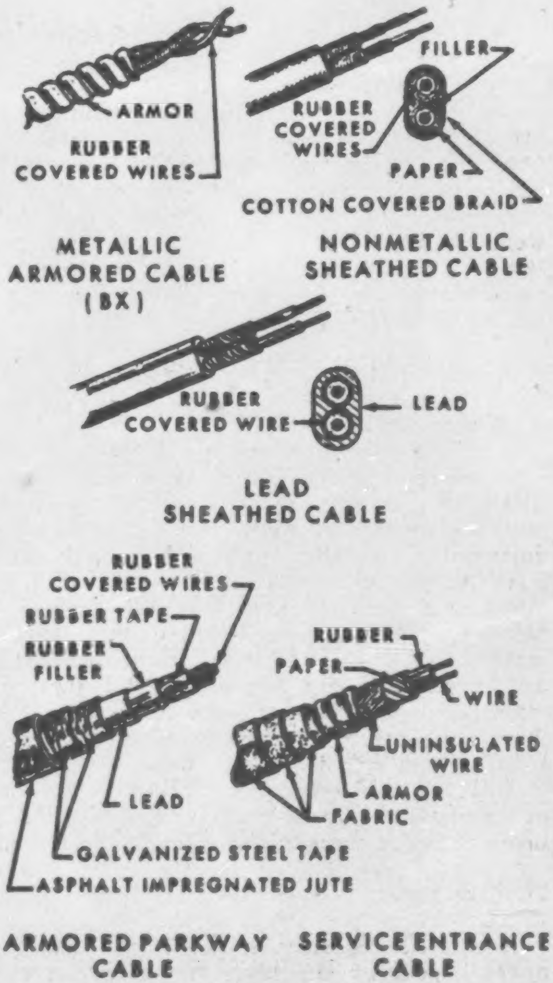
The type of wire used to conduct current from outlet boxes to sockets in the lighting fixtures is called fixture wire. It is usually size 16 or 18 AWG, stranded for flexibility.

CABLES

A cable is an assembly of two or more conductors insulated from each other with an additional insulating or protective shield formed or wound around the group of conductors (fig. 8-2). A cable that contains two No. 12 wires is known as 12-2; if it contains three No. 12 wires, it is called 12-3. If a cable has two insulated No. 14 wires, as well as an uninsulated grounding wire, it is referred to as 14-2 with ground. This cable would contain one black and one white insulated wire. If it contains three insulated wires, the third wire is red.

Nonmetallic Sheathed Cable

Nonmetallic sheathed cable is usually called Romex, its trade name. It is the cable shown in the upper right-hand corner of figure 8-2. At one time, this cable consisted of two or three conductors, insulated with rubber or thermoplastic, with paper or jute insulation wound over the rubber or thermoplastic, and an overall braid covering the combined conductors. This type of cable is still found in many places either with or without a bare (uninsulated ground wire. Now, Romex cable is required to have a ground wire. A ground wire is used to ensure the grounding of all metal boxes in the circuit, and also furnishes the ground for grounded type convenience outlets.


ARMOR
RUBBER COVERED WIRES
FILLER
RUBBER COVERED WIRES
PAPER
COTTON COVERED BRAID
METALLIC ARMORED CABLE (BX)
NONMETALLIC SHEATHED CABLE
RUBBER COVERED WIRE
LEAD
LEAD SHEATHED CABLE
RUBBER COVERED WIRES
RUBBER TAPE
RUBBER FILLER
LEAD
GALVANIZED STEEL TAPE
ASPHALT IMPREGNATED JUTE
RUBBER
PAPER
WIRE
UNINSULATED WIRE
ARMOR
FABRIC
ARMORED PARKWAY CABLE
SERVICE ENTRANCE CABLE

73.302

Figure 8-2.—Multiconductor cables.

Romex is available in sizes 14 to 2 AWG with 2 or 3 conductors. Sizes 14, 12, and 10 are solid wires. Sizes 8 to 2 AWG are stranded conductors to a cable. Romex must be secured at intervals of not more than 4 1/2 ft and within 12 in. of each outlet box of fittings, except where finished in walls.

In naval installations Romex is used primarily for temporary work, such as on quonset huts. Civilian contractors, however, use it extensively for residential wiring. The NEC does not permit its use as service entrance cable, in commercial garages, in theaters built for more than 200 spectators, in storage battery rooms, in any hazardous location, or embedded in concrete. All connections in Romex must be made at junction or outlet boxes, and squeeze type connectors must be used for securing the cable to boxes.

In most installations where Romex is permitted, a ground wire must be used with the cable to furnish a continuous ground throughout the circuit. This ground wire is fastened under a screw in each outlet box to which the cable is connected. Another way to secure the ground wire is to wrap it backward over the braid in a close wrap and under the Romex clamp. This makes a very good bond. When using grounding type duplex receptacles, the ground wire can be fastened under the green grounding screw.

When making bends in Romex, the radius of the bend should be not less than five times the diameter of the cable.

BX Cable

BX, an armored metallic cable, is also used on naval installations for temporary wiring but, unlike Romex, its use in civilian installations is restricted. Most city building codes restrict the use of BX to oil burner control circuits and the like. A difficulty with BX is the fact that it tends to ground after installation. Small metal burrs on the armor can, because of vibration, penetrate the insulation and cause a ground. The trouble and expense involved in clearing a ground behind the wall covering, after a building is finished, can be easily imagined.

BX, like Romex, must be run continuous from box to box, with no splicing allowed between boxes. It must be secured at intervals not greater than 4 1/2 ft and within 12 in. from each outlet box or fitting, except where fished in walls. It must be secured to boxes with a squeeze-type connector. It is cut with a fine-tooth hacksaw, and a fiber bushing is installed over the conductors at each cut.

BX comes in sizes from 14 to 2 AWG and in cables containing 1, 2, 3, or 4 conductors. The armor on the cable furnishes a continuous ground between boxes.

Flexible Cord

A flexible cord is made up of two or more conductors, each insulated from the other, and usually fine-stranded. Flexible cord is used for such purposes as the connection of portable lamps, tools, and appliances; for elevator cables; and for the connection of stationary equipment in which connections must be frequently interchanged. It must not be used as a substitute for fixed wiring; or run through holes in walls, ceilings, or floors; or run through doorways, windows, or similar openings. It may not be attached to building surfaces or concealed behind building walls, ceilings, or floors.

Finally, flexible cord may be used only in continuous lengths — meaning that splices or taps in it are forbidden.

Insulation

Electrical conductors are available with various kinds of insulation such as rubber, thermoplastic, varnished cambric and asbestos. Paper, glass, silk and enamel are also used to insulate conductors, but with must less frequency than those previously mentioned.

The NEC recommends insulations of various kinds for use in dry, damp, and wet locations. A dry location is one which may become only temporarily subject to dampness or wetness. A damp location requires moisture-resistant insulation because it is subject to a moderate degree of moisture. Underground installations, those in concrete slabs and masonry, those in direct contact with the earth, and those subject to saturation with water or other liquids are considered wet locations. Just as humidity affects the choice of insulation for cables, temperature is also a factor to be considered. Different insulations have different maximum temperature ratings. Check the NEC to be sure you are using the appropriate insulation for the location and temperatures in which the conductors will operate. Some examples of the composition of insulation, the locations in which they are used, and their maximum temperatures follow.

Type RH is a heat-resistant compound which will stand higher temperatures than type R. The maximum temperature for RH is 167° F. It is used in dry locations.

Type RHW is a moisture-resistant rubber compound for use where the wire may be subject to wet conditions. The maximum temperature rating is 167° F. RHW is used in both wet and dry locations.

Type RUH is a very high grade rubber compound, consisting of 90 percent grainless rubber known as latex rubber. This type is often used for direct burial in dry locations. Maximum temperature rating is 140° F.

Common grades of thermoplastic insulation are type T, type TW, and type TA. Type T is suitable only for dry locations with maximum temperature of 140° F. Type TW is moisture-resistant. Again maximum temperature rating is 140° F. Type TA is a thermoplastic-asbestos compound which combines the characteristics of type T and type TW, and has a maximum temperature rating of 194° F. Its use is restricted to switchboard wiring.

Thermoplastic insulation has the advantages of long life, toughness, and a dielectric strength (that is, a capacity for insulating) equal to that of rubber. It requires no protective covering over the insulation.

Varnished cambric insulation is, in most respects, midway between rubber and paper in insulating quality. It is more flexible than paper but not as flexible as rubber. Its dielectric strength is greater than that of rubber, but not as great as that of impregnated paper. Varnished cambric insulation is not adversely affected by ordinary oils and greases. It is made in two types: the standard with a black finish, and the heat-resisting with a yellow finish. It is used on motor leads, transformer leads, and high-voltage cables. Its use is restricted to dry locations.

Asbestos insulation has, as the name implies, the highest capacity for resisting heat. Consequently, it is used for temperatures beyond the maximum limits set for other types of insulation. However, it is not satisfactory for damp or wet locations, and is limited to a maximum of 300 volts.

RIGID CONDUIT

Rigid steel conduit may be either black-enamel finished, sherardized (zinc-coated by heat), or galvanized. Black enamel and sherardized are not used much in the Navy, because these types deteriorate in damp locations or when exposed to the elements. The galvanized type can be installed outside, inside, or embedded in concrete, even in wet locations.

When conduit is installed in concrete, it must be embedded in the concrete, not in a cinder bed below it. In some overseas locations, the conduit must be given a good coat of red lead or asphalt paint as a preservative against corrosion caused by beach sand in the concrete and/or chemicals in the soil.

Rigid conduit comes in 10-ft lengths, threaded on both ends, each length having a coupling on one end for joining lengths together. Sizes range from 1/2 in. to 6 in. in diameter.

Cutting and Threading

The use of rigid conduit involves a good deal of cutting and threading of lengths. It is best to cut with a hacksaw or special conduit cutter. An ordinary revolving wheel pipe cutter leaves a heavy inside ridge that is difficult to remove and tends to jam the passing through of conductors. Always ensure that you make a cut at right angles to the axis of the pipe.

After the pipe is cut to the proper length, use a reamer to remove all burrs from the inside of the sawed end. The conduit should be held in a vise during cutting and reaming. If a regular reamer is not available, a large rattail or half-round file can be used to remove burrs. However, no matter what burring tool you use, you must get a smooth inside finish to allow for passage of the conductors.

The next step is thread-cutting on the cutoff end. For the smaller pipe you use a ratchet-type die that turns directly with the handle. On larger pipe you use a die with a mechanical advantage—that is, one on which the die makes only a part of a revolution when the handle makes a complete revolution.

A conduit-threading die, like a plumber's die, makes a tapered thread, so that a coupling starts rather loosely but binds hard as it is set up. This tight connection serves two purposes: (1) it makes a watertight joint, and (2) it makes a good electrical connection for a continuous ground throughout the length of the conduit. To ensure a tight connection when it is impossible to screw a piece of pipe into a coupling, a special type of split coupling called Erickson coupling is used. It is somewhat similar to a water-pipe union, but is used without gasket or ground joint.

Manual Bending

In any conduit job you will have to make bends of various shapes, such as right-angle or 90-degree bends, offsets, and saddles. For smaller pipe this is done with a bending tool which is commonly called a hickey.

The procedure illustrated in figure 8-3 is recommended as one method of making a right-angle bend in a length of 1/2-inch conduit using a hickey. If a 90-degree bend is to be made in a length of conduit at a distance of 20 inches from one end, the electrician must:

1. Mark off 20 inches from the end of the conduit.

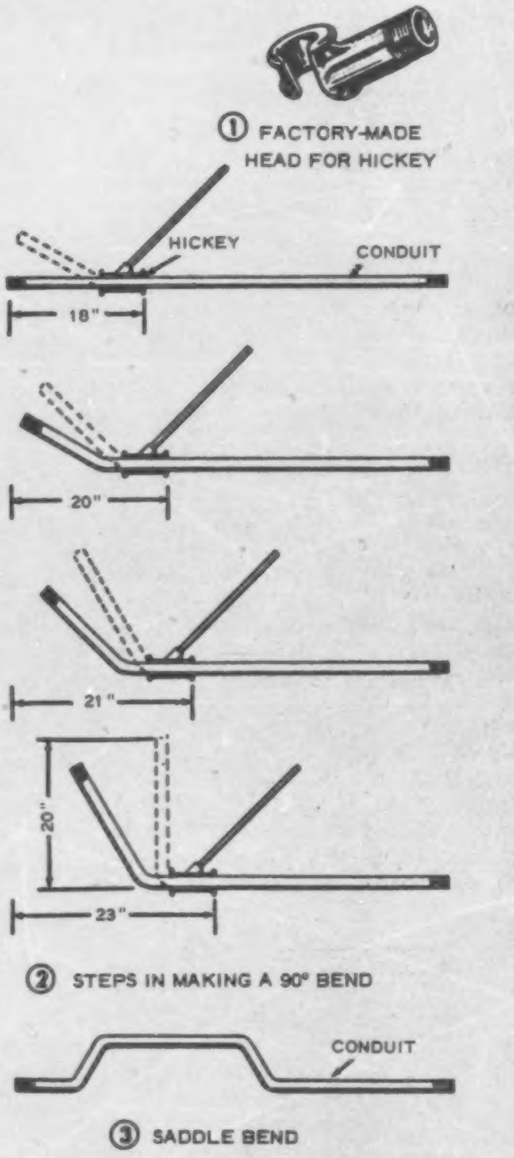
2. Place the conduit hickey 2 inches in front of the 20-inch mark and bend the conduit about 25 degrees.

3. Move the bender to the 20-inch mark and bring the bend up to 45 degrees.

4. Move the bender about 1 inch behind the 20-inch mark and bring the conduit up to 70 degrees.

5. Move the hickey back about 2 inches behind the 20-inch mark and bring the bend up to 90 degrees.

When bending conduit beyond 90° never make a sudden, sharp bend which may cause flattening of the pipe. Make a bend in a series of gradual movements. Bend a small amount; then move the bender a short distance and bend again.



73.304

Figure 8-3.—Bending rigid conduit with a hickey.

Miscellaneous conduit bends such as the saddle bend shown in figure 8-3 can be made more accurately if the contour of the bend is drawn with chalk on the floor and the bend in the pipe is matched with the chalk diagram as the bend is formed. Conduit in excess of 1 inch is usually bent by a hydraulic bender.

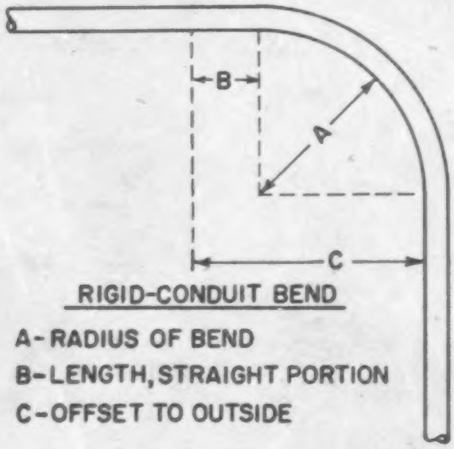
Hydraulic Bending

A hydraulic bender speeds conduit and pipe installations by means of a powerful force, applied smoothly to the pipe, resulting in accurate bends without kinks or damage.

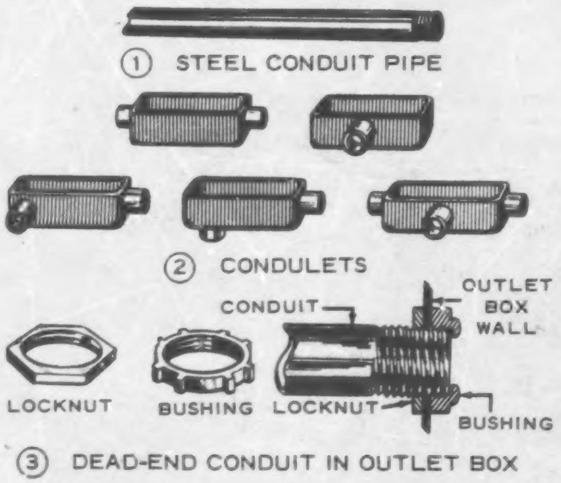
A portable hydraulic bender may be operated by a suitable electric motor, or manually by a hydraulic hand pump. A bending ram assembly which can be quickly disconnected completes the unit. For a single conductor which is not lead-covered, the bend must have a minimum radius of six times the inside diameter of the pipe; for lead-covered conductors the radius of a conduit bend must be at least 10 times the inside diameter of the conduit. Figure 8-4 illustrates what is meant by the radius of bend. Making a quick, neat bend is a job that requires a lot of practice.

Fittings

There are two types of fittings for conduit: the standard size outlet box (fig. 8-5, view 2) and the junction or pull box. The standard outlet box fittings are classified as type F and are used normally in exposed installations for receptacles or switches. The junction or pull box fittings are used to provide intermediate points in long conduit runs for pullthrough of wire or junctions for several conduit runs. Conduit fittings are not permitted in concealed installations where they will not be accessible. Boxes used with rigid conduit are supplied with removable knockouts. Bushings and locknuts are provided for attachment of the conduit to the boxes, as shown in figure 8-5, view 3.



73.17
Figure 8-4.—Dimensions of a conduit bend.



73.409
Figure 8-5.—Rigid conduit and fittings.

Boxes to be used in wet locations must have threaded hubs which the conduit is screwed into. Other accessories are shown in figure 8-6. The threaded coupling is furnished with each length of rigid conduit. Standard conduit elbows are manufactured for use where 90° bends are required. Unions permit the opening of a conduit at any point without sawing or breaking the conduit run.

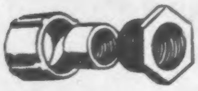
Condulets are a convenient way of making bends, especially in conduit which will be exposed to the elements. However, a condulet must never be concealed in a wall or elsewhere, because the cover must always be accessible. Condulets may be used to reduce the number of bends made in a run of conduit. The NEC specifies not more than four 90-degree bends between pull boxes (NEC article 370-18) but a condulet may be used in place of a pull box.

The LB condulet shown in figure 8-7 is very convenient for sharp corners. The LB condulet can be opened at the back to allow the wire to be pulled without binding against the conduit wall. Be sure that covers are set on securely. For condulets exposed to the elements, place a gasket under the cover to ensure that it is watertight.

Neatness is a must in bending, conduit work, and any other electrical work. Bends which are

① CONDUIT COUPLING

② CONDUIT ELBOW



③ CONDUIT UNION

73.410

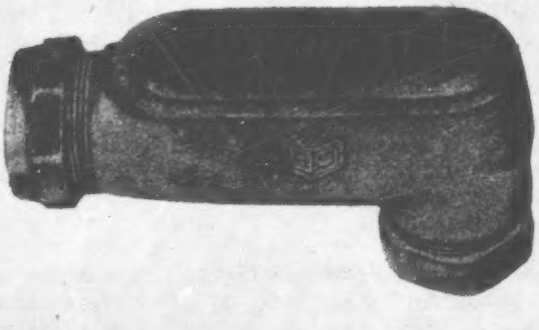
Figure 8-6.—Rigid conduit accessories.

not uniform detract from the appearance of the job. The method of securing conduit depends on its size and type. A one-hole strap is the type of fastener most frequently used. The manner of fastening depends on the material to which it is fastened. Hollow walls require toggle bolts; concrete or block walls require a lead anchor set in a drilled hole; steel construction requires a bolt set in a drilled hole.

ELECTRIC METALLIC TUBING (THIN-WALL OR EMT)

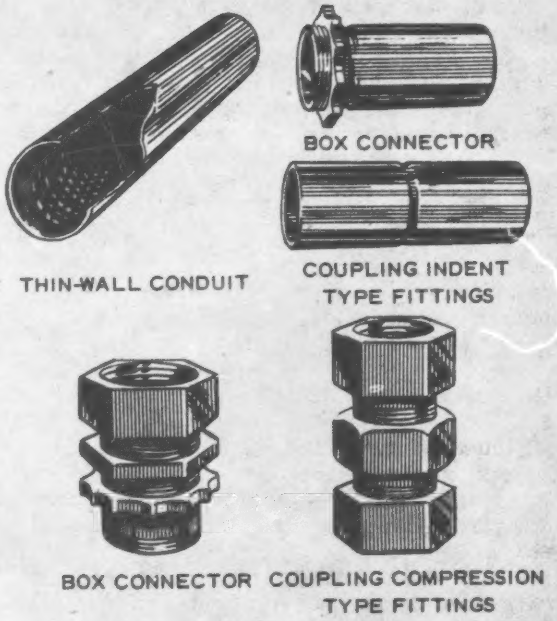
Thin-wall conduit is a metallic tubing which can be used for either exposed or concealed electrical work. This conduit, as its name implies, has a thinner wall than rigid conduit but has the same cross sectional area as rigid conduit. It is available in sizes from 1/2 inch to 4 inches in diameter. All couplings and connections to boxes are threadless and are of either the clamp or compression type. Some common types are shown in figure 8-8. The compression type is waterproof. The indent and setscrew types are not waterproof.

Extreme care must be used when bending metallic tubing to avoid kinking the pipe or reducing the inside area. The thin-wall conduit bender (fig. 8-9, view 1) has a cast steel head which is attached to a steel pipe handle approximately 4 feet long. It is used in the field to form thin-wall conduit into standard and offset bends. Benders are made for each size of conduit and must be used only on those sizes for which they are designed.



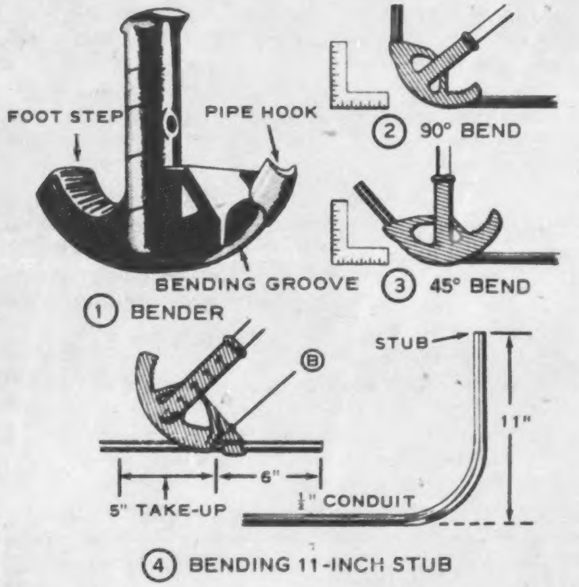
73.18

Figure 8-7.—LB condulet.


BOX CONNECTOR
THIN-WALL CONDUIT
COUPLING INDENT TYPE FITTINGS
BOX CONNECTOR
COUPLING COMPRESSION TYPE FITTINGS

73.411

Figure 8-8.—Thin-wall conduit and fittings.



73.412
Figure 8-9.—Bending thin-wall conduit.

To bend conduit, first place the conduit on a level surface and hook the end of the bender under the conduit's stub end. Then, with the bending groove over the conduit and using a steady and continuous force, while firmly holding the conduit and bender with the body, push down on the handle and step on the foot step, bending the conduit to the desired angle. Takeup height is shown in figure 8-9, view 4. You can cut thin-wall conduit using a 32-teeth-to-the-inch hacksaw blade, keeping the cut at right angles to the axis of the pipe.

INTERMEDIATE METAL CONDUIT

Intermediate metal conduit is a conduit with a wall thickness less than rigid metal conduit but greater than that of EMT. It uses the same standard fittings as rigid metal conduit and has the same general application as rigid metal conduit, except that it must not be used in hazardous locations. Its lighter weight makes for easier handling and lower labor units (estimates) than rigid conduit. Because it has the same outside diameter as rigid metal conduit of the same size, it has greater interior cross sectional area. This does not permit the use of more conductors than can be used in the same size of rigid metal conduit but does make wire pulling easier.

PVC CONDUIT

Rigid polyvinyl chloride (PVC) conduit has been developed by many manufacturers. Some of the advantages of PVC conduit are: the light handling weight, high corrosion resistance, ease of installation, leakproof joints and easy wire pulling (due to the mirror-like walls). Refer to NEC, articles 347, 514-8, and 515-5 for installation requirements.

Joining PVC

Permanent joints are made quickly in PVC conduit by cutting the conduit with a handsaw or hacksaw and removing the burrs with a pocketknife. The surfaces to be joined are wiped clean and a light coat of solvent cement is applied to the inside of the coupling or fitting and outside of the conduit. After the conduit is inserted all the way into the fitting, it is given a quarter turn to ensure good distribution of the cement. Any excess is wiped off.

A variety of threaded PVC fittings is available from manufacturers. Their use is covered in article 370 of the NEC. Installation using the solvent-welding technique described in the previous paragraph, however, is preferred because the joints are water- and vaporproof.

Bending PVC

Bending of PVC conduit is accomplished very easily by application of heat from a hot-air, cold-air blower to a section of PVC rigid conduit. Gradual pressure is applied to form the bend desired. When the desired curve is achieved, the cold air from the blower is then applied to set the bend. Be sure to compensate for any spring back. Remember, too, that PVC conduit should be bent on a radius at least 10 times its diameter.

FLEXIBLE CONDUIT

Flexible conduit (also called Greenfield) is composed of a spirally wrapped metal band wound on itself and interlocked so that it makes a cylindrical metal flexible tube of high mechanical strength. Greenfield can be used in locations where rigid conduit is not adaptable. It is easily fished, requires no elbow fittings, and comes in diameters from 1/2 inch to 3 inches.

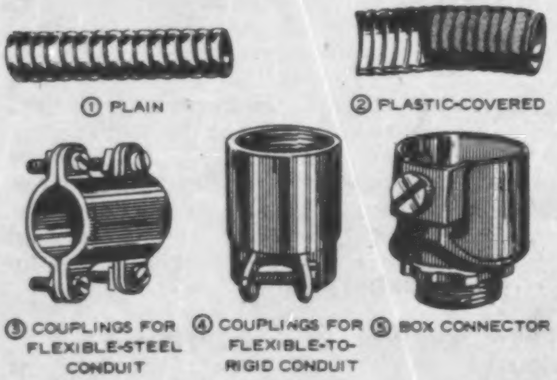
The only fittings required for Greenfield are squeeze type fittings for connecting the pipe to boxes. (See fig. 8-10.) A fine-tooth hacksaw should be used for cutting, and again the cut should be square.

Greenfield is available in two types: the standard unfinished-metal type, and a moisture-resistant type called sealtite, which has an outside jacket of latex or plastic. The moisture-resistant type is not intended for general use, but only for connecting motors or portable equipment in damp or wet locations where flexibility of connections is desired. It must be used with connectors approved for the purpose.

The standard metal Greenfield is used primarily for connecting motors mounted on sliding bases. It is also used for equipment which cannot be easily wired with rigid conduit and requires conduit which can be fished in walls or between the floor above and ceiling below. It is seldom used in wet or hazardous locations except as expressly permitted by the NEC.

WIRING TROUGHS

Wiring troughs are useful in any location where a large number of conduits enter a panelboard. One large conduit can be used to carry a number of conductors from the panel to the trough and smaller conduits branch out from the trough to the various circuits. The trough can also be used for feeders from the entrance switch to the panelboard. An example of how wiring troughs are used is shown later when service entrances are discussed.


① PLAIN
② PLASTIC-COVERED
③ COUPLINGS FOR FLEXIBLE-STEEL CONDUIT
④ COUPLINGS FOR FLEXIBLE-TO-RIGID CONDUIT
⑤ BOX CONNECTOR

73.413

Figure 8-10.—Greenfield flexible conduit and fittings.

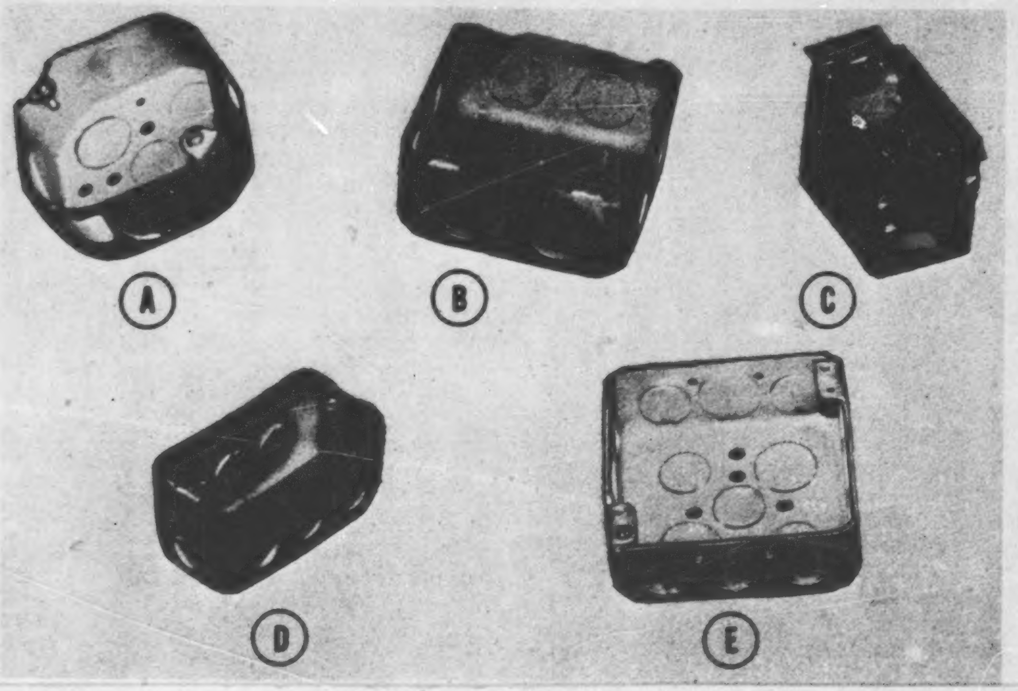
BOXES

A box is a container, set flush or nearly flush with the wall, floor, or ceiling, into which the outlet, receptacle, or switch will be inserted and fastened. A 4-in. octagon box used for ceiling outlets is shown in view A of figure 8-11. This box is made with 1/2-in. or 3/4-in. knockouts—that is, indentations which can be knocked out to make holes for the admission of conductors and connectors. View B shows a 4 11/16-in. square box used for heavy-duty installation, such as for a range or dryer receptacle. It is made with knockouts up to 1 in. in diameter. The box in view C is a sectional or gem box used for switches or receptacles. By loosening a screw you can remove a side panel, so that two or more boxes can be ganged (combined) to install more than one switch or receptacle at a location. View D illustrates a utility (called a handy) box, made with 1/2- or 3/4-in. knockouts and used principally for open type work. The box in view E is a 4-in. square box with 1/2-or 3/4-in. knockouts, used quite often for switch or receptacle installation. It is equipped with plaster rings having flanges of various depths, so that the box may be set in plaster walls of various thicknesses.

Besides the boxes shown, there are special boxes for switches when you have more than two switches at a location. These are called conduit gang boxes, and they are made to accommodate 3, 4, 5, or 6 switches. Each size has a cover made to fit.

A ceiling box may be fastened to a wooden header set between the ceiling joists, or it may be fastened to a bar hanger as shown in figure 8-12.

The NEC requires that outlet boxes be 1 1/2 in. deep, except when the use of a box of this depth "will result in injury to the building structure or is impracticable," in which case a box not less than 1/2 in. deep may be used. Switch boxes range in depth from 1 1/2 in. to a maximum of 3 1/2 in. The 2 1/2 in. depth



73.15

Figure 8-11.—Types of outlet, receptacle and switch boxes.

is the most widely used. The 1 1/2 in. depth boxes are used when two boxes in two different rooms happen to come back-to-back in the wall separating the rooms.

Nonmetallic boxes are made of plastic material and are used with nonmetallic-sheathed cable. Many types are available with mounting brackets or nails for installing directly on timbers in buildings. These boxes are of one-piece construction and cannot be ganged, but readymade 2-gang and 3-gang boxes are available. Connectors are not needed at the box but the cable must be supported within 8 in. of the box on new work.

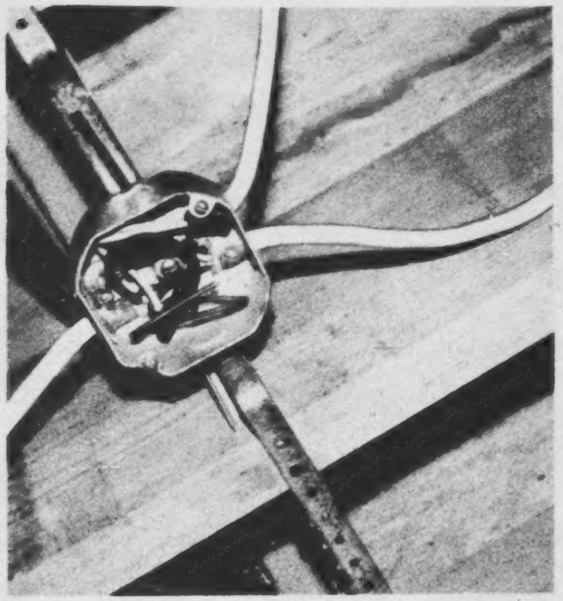
To locate outlet, receptacle, and switch boxes you follow the electrical floor plan. Assume you are working on a new building in which all wiring will be concealed by wall, ceiling, or floor covering. The NEC requires that the outside edges of outlet and switch boxes without flush plates NOT be recessed more than 1/4 in. below the surface of the finished wall. Boxes having flush plates must not project beyond the finished wall surface. Wall outlets are to be located the following distances above finished floor surfaces: duplex receptacles, 12 in.; toggle switches, 48 in.; wall fan receptacles, 78 in.; overcounter receptacles, 48 in. All these measurements are from the finished floor surface to the middle of the receptacle. The usual way to mount a wall box in a frame wall is on a wood header inserted between studs.

For exposed wiring installed in a building after completion of the wall finish, the procedure for securing boxes varies according to the wall or ceiling surface material. Boxes are fastened to a wood surface with wood screws; for plasterboard or plywood, toggle bolts are better; for concrete you must drill holes for setting lead anchors.

RECEPTACLES

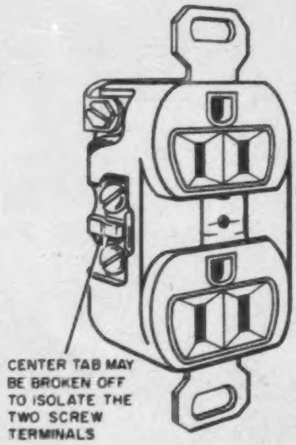
Receptacles used in interior wiring are discussed below in the order of their frequency of use.

A convenience outlet (fig. 8-13) is a duplex receptacle with two vertical or T-slots and a



73.16

Figure 8-12.—Ceiling outlet box on bar hanger.


CENTER TAB MAY BE BROKEN OFF TO ISOLATE THE TWO SCREW TERMINALS

73.28

Figure 8-13.—Duplex convenience outlet.

round contact for the ground. This ground is connected to the frame of the receptacle, and is grounded to the box by way of the screws that secure the receptacle to the box.

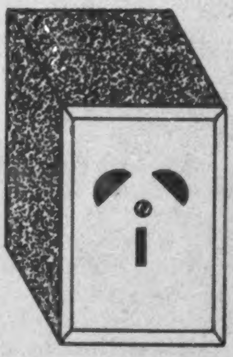
When you desire to have the two outlets on a receptacle supplied by two separate power sources, break the center tab between the two screw terminals on each side. Then, wire the same as you would single outlets. Most floor receptacles are single receptacles with two vertical or T-slots.

A range receptacle (fig. 8-14) may be a surface type or a flush type. It has two slanted contacts and one vertical contact, and is rated at 50 amps. Receptacles for clothes dryers are similar, but are rated at 30 amps. Range and dryer receptacles are rated at 250 volts, and are used with three-wire, 115/230 volts, two hot wires and a neutral. A receptacle for use with an air-conditioner taking 230 volts is made with two horizontal slots and one round contact for the ground.

SWITCHES

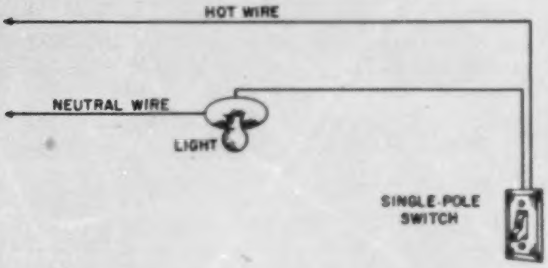
For interior wiring you use single-pole, 3-way, or 4-way toggle switches. Most of the switches you use will be single-pole, but occasionally you will have to install a 3-way system, and on rare occasions a 4-way system. Still another system of switching, called the low-voltage system, is coming into use.

A single-pole switch is a one-blade, on-and-off switch which may be installed singly or in multiples of two or more in the same metal box. (Boxes were explained earlier in this chapter.) In wiring a single-pole switch, connect the colored wires to the two contacts on the switch, the switch being always in series with the hot wire. Figure 8-15 shows a single-pole switch circuit.



73.29

Figure 8-14.—Range receptacle.

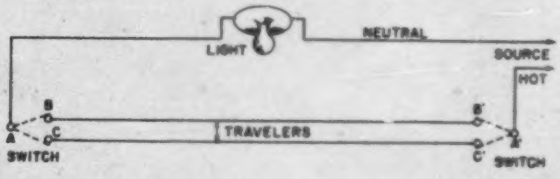

HOT WIRE
NEUTRAL WIRE
LIGHT
SINGLE-POLE SWITCH

73.24
Figure 8-15.—Single-pole switch circuit.

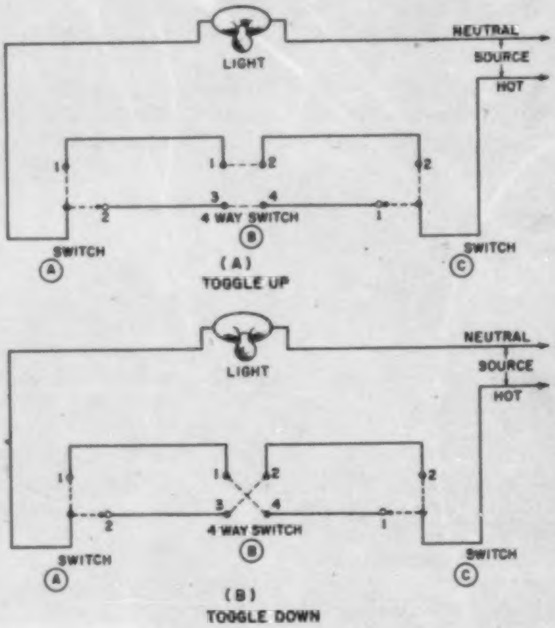
In a 3-way switch circuit there are two positions, either of which may be used to turn a light on or off. The typical situation is one in which one switch is at the head of a stairway and the other at the foot. Figure 8-16 shows how the circuit functions.

Terminals A and A' are the common terminals, and switch operation connects them either to B or C and B' and C', respectively. Either switch will operate to close or open the circuit, turning the lights on or off.

By tracing the circuit in figure 8-16 from the source, you can see that the hot wire goes to the first switch, through the closed switch blade to the other switch by way of the traveler, and through this switch to the light. By changing the position of either of the switches, the circuit is broken.


LIGHT
NEUTRAL
SOURCE
HOT
B
B'
A
C
TRAVELERS
C'
A'
SWITCH
SWITCH

73.25
Figure 8-16—Three-way switch circuit.


LIGHT
NEUTRAL
SOURCE
HOT
1
1
2
2
3
4
2
1
4 WAY SWITCH
B
SWITCH
A
(A)
TOGGLE UP
SWITCH
C
LIGHT
NEUTRAL
SOURCE
HOT
1
1
2
2
3
4
2
1
4 WAY SWITCH
B
SWITCH
A
(B)
TOGGLE DOWN
SWITCH
C

73.26
Figure 8-17.—Four-way switch circuit.

A 4-way switch is an extension of a 3-way circuit by the addition of a 4-way switch in series with the two traveler wires. Figure 8-17, view A shows how a 4-way circuit is wired. By tracing this circuit from the source you observe the hot wire connected to switch (C) passing through position 1, which is closed. The hot wire continues to point 4 on the 4-way switch (B). At this time the toggle on switch (B) is in the UP position and contact is made from point 4 to point 3. The hot wire continues on through the traveler to switch (A), and through position 2 (which is closed) to the light.

Suppose, now, that you want to turn the light off at 4-way switch (B). By putting the toggle in OFF (down) position you change the switch blades from point 1 to 2 and 3 to 4 to points 1 to 4 and 2 to 3. (See fig. 8-17, view B.) If you now retrace the circuit from switch (B) to switch (A), you will find that it goes from point 4 to point 1 on switch (B) and through the traveler to switch (A), where the circuit is broken by the blade in open position.

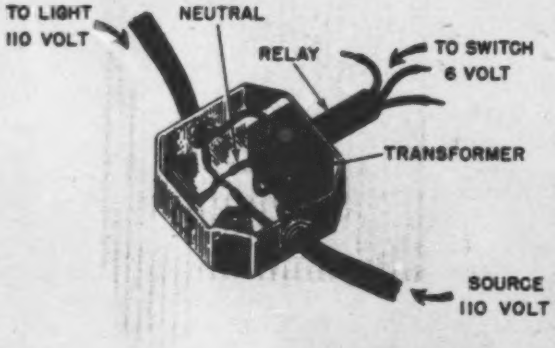
Most 4-way switches have a wiring diagram on the switch body. Some, however, have the diagram on the carton the switch is packed in. This diagram must be preserved. If it gets lost you will have to use an ohmmeter or battery to trace the movement of the blades when you change the position of the toggle.

Note that 3-and 4-way switches may be used as single-pole switches, and 4-way switches may be used as 3-way switches. Some activities may install all small-wattage, 4-way switches for all lighting circuits, to reduce their inventories. However, 3- and 4-way switches are usually larger than single-pole switches and take up more box room. The size of a switch depends on its ampacity (rated maximum amperage). The ampacity and maximum allowable voltage are stamped on the switch, and must be considered when ordering equipment for the job.

Low-voltage wiring is a switching system which employs a transformer and low-voltage relay. A low-voltage conductor (three No. 18 AWG wires) is used from the outlet to the switch box instead of conduit or Romex. Some systems use a master transformer to reduce the voltage from 110 volts to 6 volts, but one system uses a combination transformer. (A relay is a protective device which opens a circuit when current in a line exceeds the rated value of the relay at the outlet box.) A combination transformer ensures that only one light is affected in case of transformer failure.

The transformer-relay combination is installed in the outlet box for the light being controlled, with the transformer inside the outlet box and the relay protruding outside through a knockout, as shown in figure 8-18.

In the low-voltage system as many switches as are required can be installed for any given light, or a master switch can be installed to turn on as many as eight lights simultaneously.



73.27

Figure 8-18.—Low-voltage relay and transformer.

There is no necessity for 3-way or 4-way switches, because the switches are connected in parallel, and the movement of the switch toggle in one direction pulls the relay one way (off the circuit) and energizes the light. A movement of the toggle in the other direction pulls the relay the opposite way (into the circuit) and breaks the circuit.

EXPLOSION-PROOF FITTINGS

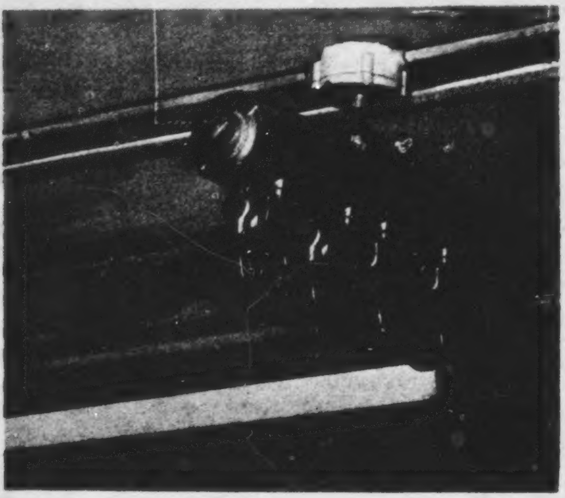
In locations specified by the NEC (articles 510 through 517) as explosion-hazardous, you must install explosion-proof fittings. Locations are classed by number in descending order of danger: class 1, division 1, highly hazardous; class 1, division 2, slightly less hazardous; and so on.

As an example of explosion-proofing; in a gasoline filling station the pump island is classed as class 1, division 1. All conduits in this area must be sealed with a special sealing fitting, and on conduit for lights above the pumps the sealing fitting must be located at a height of not less than 4 ft above the driveway surface. No junction boxes (explained in NEC article 370-18) or condulets may be used in the pump area. Conduits running from pumps to panels in the building must be sealed not less than 18 in. above the building finished floor to avoid fumes from the gasoline pumps. An approved seal must also be installed on any conduit entering or leaving a dispensing pump or other enclosure on the pump island.

Inside the building of a gasoline station the class 1, division 1, space extends 18 in. above the floor. Space above the 18-in. level is classed as class 1, division 2.

Paint spray booths are listed as class 1, division 1, and therefore all fixtures, exhaust fans, air compressors, or other electrical appliances located in such booths must be explosion-proof, as well as all switches, convenience outlets, and motor starters.

Figure 8-19 shows an explosion-proof fluorescent lighting fixture for installation in a paint spray room. In this fixture the fluorescent tubes are sealed in a larger glass tube. The four tube seal ends can be seen in the figure. The ballast (explained in NEC article 410, part P) is enclosed in the container above the tube seals.



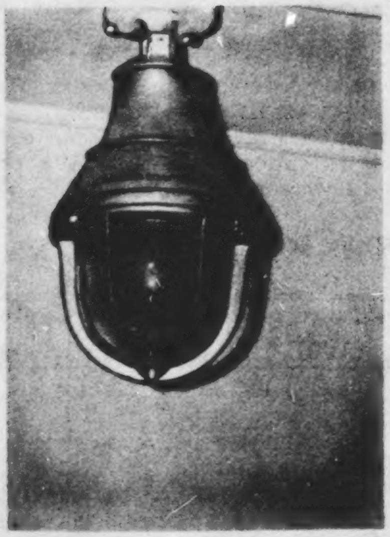
73.19
Figure 8-19.—Explosion-proof fluorescent fixture.

Figure 8-20 shows an explosion-proof incandescent lighting fixture; figure 8-21, an explosion-proof on-and-off switch for lighting.

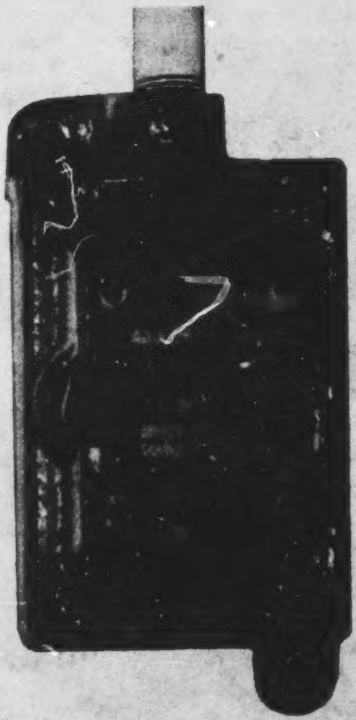
When the interior wiring system has been completely installed, make an overall inspection to be sure that good installation practices have been observed and all connections are correct. While making this check, don't forget neatness. Make sure that ground connections are tight and that ground wire is protected against injury. Be sure that all connections in entrance switch and panelboards are tight. See that all metal noncurrent-carrying parts of portable equipment are grounded.

INSTALLING THE SERVICE

The term "service" means, in general, the electrical system which brings the power from the pole or other point on the powerline to the point in the building from which it is distributed to the building circuits.



73.20
Figure 8-20.—Incandescent explosion-proof fixture.



73.21
Figure 8-21.—Explosion-proof on-and-off lighting switch.

The service for a building consists of two parts: the service conductors and the service equipment. The service conductors are divided into service drop conductors and service entrance conductors. The SERVICE DROP CONDUCTORS are run from the pole to the building. The SERVICE ENTRANCE CONDUCTORS connect the drop conductors at a point outside the building and must be run in rigid conduit to the service equipment inside the building.

The service equipment consists of circuit breakers, switches, and fuses. This equipment is located near the point of entrance of the supply conductors to a building, and constitutes the main control and means of cutoff for the electrical supply to that building.

SERVICE DROP CONDUCTORS

Service drop conductors may consist of an approved multiconductor cable or they may be open single conductors. In either case they must have thermoplastic, rubber, or other weatherproof insulation, except that a grounded conductor may be uninsulated if the maximum voltage to ground of any conductor does not exceed 300 volts. The current-carrying capacity of the service drop conductors must be sufficient to ensure that ample current for the prospective maximum load may be conducted without a temperature rise to a point high enough to damage the insulation. Obviously, the conductors must also have adequate mechanical strength. The NEC specifies No. 8 AWG wire as the minimum size, except that in special cases No. 12 may be used.

SERVICE ENTRANCE CONDUCTORS

Service entrance conductors in the Navy are single conductors run in rigid conduit; in civilian construction they may consist of an approved type of service entrance cable. Conductors also must have rubber or thermoplastic insulation, except that a grounded conductor may be uninsulated if the maximum voltage to ground of any conductor does not exceed 300 volts.

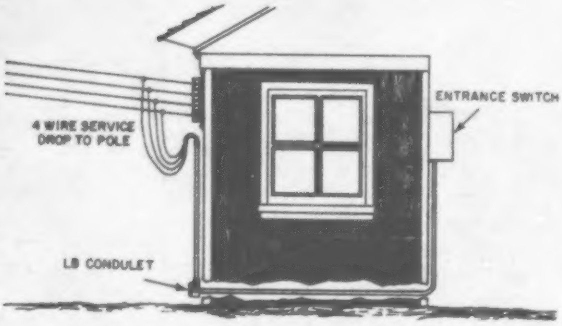
The NEC specifies No. 6 AWG wire as the minimum size conductor to be used for service entrance, except that in special cases and by special permission, No. 8 wire may be used. For a Navy man, special permission means that of higher authority. In civilian work (in most civilian communities the NEC has been incorporated into the building laws) it means that of the community's building inspectors.

Table 1 of the NEC indicates the maximum number of conductors of a given size to be used in rigid conduit for new work. Let's assume you are going to use No. 6 wire with Type THWN insulation. Using three wires (the normal number for service entrance) you see that you can use 1-inch conduit. The conduit must be continuous from the weatherhead (point where the wires enter the conduit) to the entrance switch except when a condulet (fig. 8-22) is used in place of a bend.

The conductors must be continuous from the weatherhead outside the building to the connections in the entrance service switch—meaning that no splices between these points are allowed. However, a connection is permitted,

Table 8-1.—Circuit conductor wire sizes for various motors

MOTOR HP	SINGLE-PHASE AMPS AT 110 V	WIRE SIZE (AWG)	AMPS AT 220 V	WIRE SIZE (AWG)	3-PHASE AMPS AT 220 V	WIRE SIZE (AWG)
3/4	14	12	6.9	14		
1	16	12	8	14	3.5	14
1 1/2	20	10	10	14	5	14
2			12	14	6.5	14
5			28	8	15	12
7 1/2			40	6	22	10
10					27	8
15					40	6



73.8
Figure 8-22. — Service entrance with condulet.

when properly enclosed, where an underground service conductor enters a building and is to be extended to the service or meter in another form of approved service raceway or service cable.

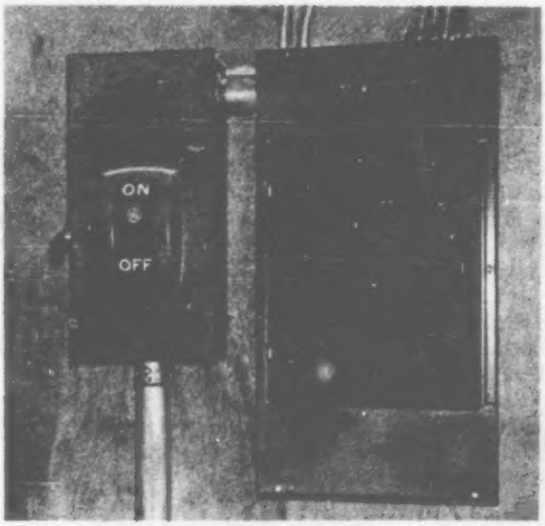
When the service is run underground, the conduit must be continuous from the pole or underground vault to the service switch. If the conduit enters the building through a concrete floor, a conduit coupling must be installed in the conduit line with the top of the coupling flush with the finished floor surface. The advantage of this is that spare conduits can be installed in the concrete floor and a plug screwed into the coupling, making a flush job. Also, if the wiring were to be removed for some reason, the open conduit could be removed from the coupling and a plug screwed into the same.

ENTRANCE SWITCHES

A service entrance switch provides a means of disconnecting the service conductors from the supply source. It may consist of a single manually operated switch or circuit breaker. It must be marked to show whether the contacts are in an open (OFF) or closed (ON) position, as illustrated in figure 8-23.

The neutral conductor must not be run straight through the service switch, without a means of disconnection. Therefore, a screw or bolted lug on the neutral terminal block should be provided for disconnecting the neutral conductor from the interior wiring system.

The NEC sets a minimum size for entrance switches at 60 amp for the fuse type and 50 amp for the circuit breaker type. A circuit breaker is a protective device which automatically opens the circuit, rather than burning out like a fuse, when the amperage exceeds that rated for the circuit breaker.



73.10
Figure 8-23. — Entrance switch marked to show open (OFF) and closed (ON) positions.

However, the NEC recommends a minimum size of 100-amp service for individual residences. An exception is that where not more than two 2-wire branch circuits are installed, a 30-amp entrance switch may be used.

No overcurrent device may be inserted in a grounded conductor except a circuit breaker which will simultaneously open all conductors of the service. EVERY ungrounded conductor must be provided with overcurrent protection.

Switches used for entrance equipment must be of an approved type. An approved type is usually a quick make-and-break type with an interlocked cover which can't be opened when the switch is in the ON position. The service conductors must be connected to the disconnecting device by pressure connectors, clamps, or other approved means; a solder lug or other type of soldered connection cannot be used.

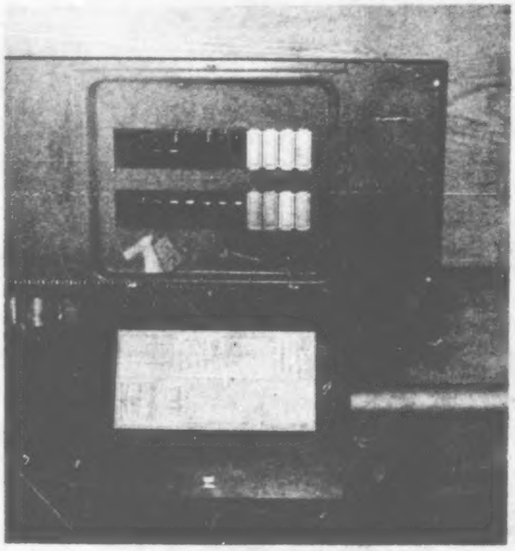
DISTRIBUTION PANELS

A panelboard is defined by the NEC as "a single panel or group of panel units designed for assembly in the form of a single panel including buses (buses and busways are explained in articles 364 and 384-21 of the Code) and with or without switches and/or automatic overcurrent protective devices for the control of light, heat, or power circuits of small individual as well as aggregate capacity, designed to be placed in a cabinet or cutout box and placed in or against a wall or partition and accessible only from the front."

As a Construction Electrician, you will be concerned mostly with the breaker panel for both light and power. (See fig. 8-24.) The breaker panel uses a thermal unit built into the switch. The breaker is preset at the factory to open automatically at a predetermined ampere setting. It may be reset to the ON position after a short cooling-off period.

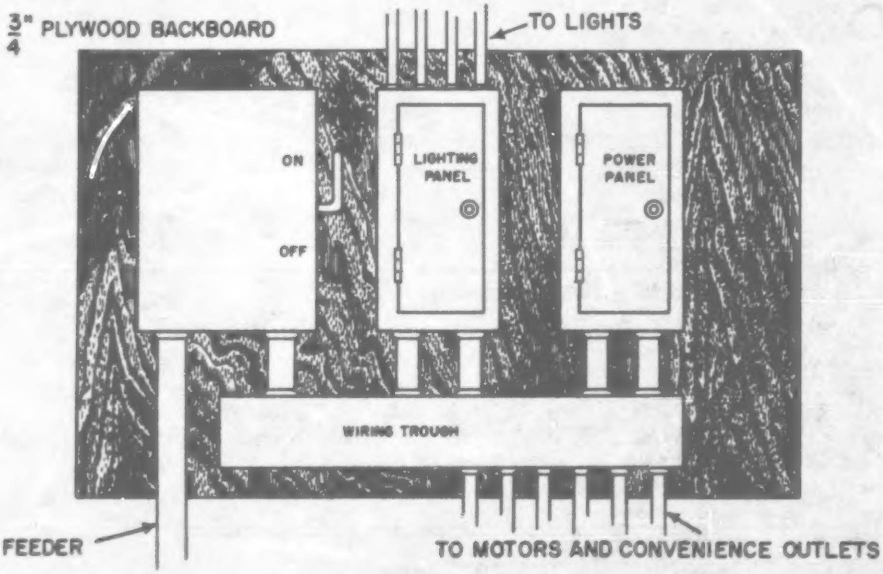
Lighting panels are normally equipped with 15-amp single-pole automatic circuit breakers, while the power panels may have 1- 2- or 3-pole automatic circuit breakers with a capacity to handle the designated load. Figure 8-25 shows a typical layout for an entrance switch, lighting panel, and power panel.

In most buildings the entrance switch and panelboards can be mounted close to each other.



73.11

Figure 8-24.—Lighting panel.



73.12

Figure 8-25.—Representative layout for entrance switch, lighting panel, and power panel.

When wiring a building that has been built previously, the best way to mount the switch and panels is to mount a sheet of plywood for a backing board. The board should be large enough to accommodate all of the equipment, be a minimum of 3/4 in. thick, and be securely fastened to the wall with wood screws, lead anchors, or toggle bolts, depending on the type of wall. The switch and panels can then be fastened to the backboard with wood screws.

If you are working in a newly constructed building where only the framework has been erected, it will be a simple matter to arrange for a concealed installation. One point to remember is that there are two types of switches and panels. The recess or flush type has a front flange that extends beyond the edges of the cabinet to cover the rough edges around the cabinet where the finish wall has been cut. Also, the flush type switch as a front control for operating the switch. The surface type switch and panel has a front cover that does not extend beyond the sides of the cabinet, and the switch may be side-operated or front-operated.

In locating panels, you must follow certain basic requirements. The panels must be placed where service and maintenance can be easily performed; they should not block any passage that is supposed to be open; they must not be in a place where they might be exposed to corrosive fumes or to dampness; and they should be located as near as possible to the center of the electrical load.

The circuits controlled at the panelboard must be clearly indicated. List them numerically, from top to bottom, with the odd numbers on the left. Put this list (called a catalog) in the slot provided for it, as shown in figure 8-24. If possible, provide for extra circuits in the new panel to accommodate future additions.

NEUTRAL WIRE

To understand the purpose of a neutral wire, bear in mind that the path traveled by electricity is always from the source around the circuit and back to the source. As the current follows this path, it energizes the fixtures and/or appliances that are connected into the circuit. You can see, therefore, how essential it is to ensure current return.

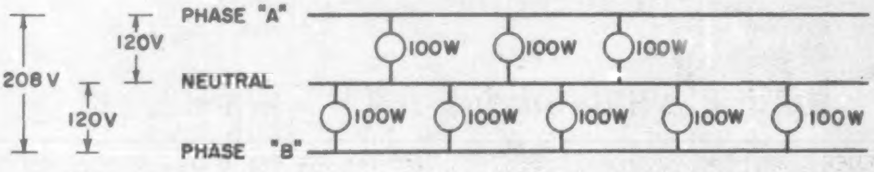
Generally speaking, the fixtures can be considered as resistances in series with the hot wires. In a balanced circuit, one hot wire carries the current to the load, while the other carries it back to the source.

The neutral wire ensures current return in an UNBALANCED circuit, as shown in figure 8-26. Here there are two hot wires and a neutral. There are three lamps connected across one hot wire and the neutral, and five lamps connected across the other hot wire and the neutral. These lamps occasion a current flow of approximately 1 ampere per lamp. It follows that the flow is 5 amps in one phase and 3 amps in the other—meaning that the circuit is unbalanced, with an unbalanced load of 5 minus 3, or 2 amps.

If each phase carried three lamps, the circuit would be balanced. But because there are two extra lamps in one phase, the neutral wire must pick up the extra load and return it to the source.

Why must the neutral have the same size as the hot wires? In this case, with all the lamps on, it must handle only 2 amps, whereas the hot wire in phase B must handle 5 amps. If the lamps in phase A were all turned off, the neutral would have to handle the full 5-amp return from phase B.

A motor in a circuit usually causes an unbalanced circuit. A motor operating on 220



73.14

Figure 8-26.—Use of neutral wire in unbalanced circuit.

volts single-phase does not have a neutral wire to aid the balance. Therefore, when a motor of this type is connected across two phases, the other phase should be given enough extra lighting load to balance the load as nearly as possible. Perfect balance is possible in theory, but not in actual practice.

With a 4-wire system, one neutral wire can be used for three circuits, provided the three are connected to opposing phases. Never use one neutral wire for two circuits connected to the same phase.

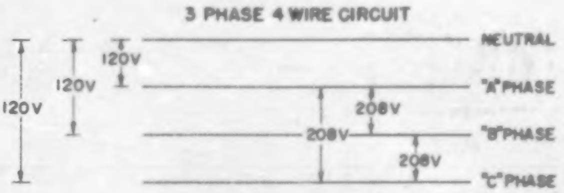
The NEUTRAL wire in a wiring system must not be confused with the equipment ground wire. The neutral wire should have white or light grey insulation; the equipment ground wire, if insulated, will always have green insulation. However, an equipment ground wire may be uninsulated.

In a 4-wire system (fig. 8-27), one of the wires is always a neutral wire, but in a 3-wire system there may or may not be a neutral wire. In a 3-wire system you may have a 3-phase circuit (3 live or hot wires), or you may have a single-phase circuit (2 hot wires and a neutral).

GROUNDING

The two types of grounds used are the system ground and the equipment ground. The system ground consists of grounding the incoming neutral wire as well as the neutral wires of the branch circuits. The equipment ground consists of grounding the metal parts of the service entrance, as well as the service entrance conduit. The equipment ground also includes grounding switchboard frames, motor, and similar equipment.

The usual method of grounding is to attach the grounding wire to a cold water pipe of the underground water system. If an underground water system is not available, driven grounds are used. Grounding systems are further discussed in chapter 9.



73.13

Figure 8-27.—Four-wire system.

LOCATING AND INSTALLING CONDUCTORS

When the service switch, panelboards, and conduits have been installed, you are ready to pull in the wires. The electrical print or plan shows the number of wires to be pulled into each individual conduit. Remember that there must always be a neutral wire in any lighting or convenience outlet circuit.

Lighting fixtures and convenience outlets are connected between a neutral and a hot wire, with the wall switches connected in series with the hot wire. Any solid color except white or green can be used for the hot wire, except that in switch leg wiring using cable, the return leg must be black. The neutral wire is always white, and equipment grounds always green, if insulated. The accepted wire color code is in NEC article 210-5.

Wires are pulled through conduit with a narrow steel tape called a fish tape. Fish tapes come in various thicknesses; on most jobs you will use the small 1/8 by 1/16 in. size.

Start this tape through the conduit at an outlet box or panelboard, as the case may be, and keep pushing the tape until it emerges at the next opening or outlet box. You secure the wires to a hook on the fish tape by removing about 3 in. of insulation from the wires and bending the bare wires over the hook. Make a few wraps of friction tape over this connection, to prevent the wires from slipping off and to provide a smooth pulling surface. In some cases you may have to put talc or a lubricant called pulling compound on the wires. Never use oil or grease for this purpose, because these substances will deteriorate the insulation.

Pull the tape and wires back through the conduit. If possible, have a man at the point where the wires enter, to keep out kinks or twists. Where wires pass through an outlet box without being tapped, pull enough wire to continue on through without making a splice, to eliminate extra splices in the box or opening.

When the wires have been pulled in throughout the conduit system, connect the proper wires to the various fixtures and outlets. Do any necessary splicing at the same time. During splicing, remember that white wires connect to white, except for Romex cable switch runs, and other colors to the same colors. In splicing joints, always be sure the joint is well soldered and taped with rubber or friction tape—or, in some places, you may use a plastic electrical tape which does not require a cover of friction tape.

Another way of insulating splices is to use an insulated wire connector, called a wire nut (fig. 8-28, view A). You screw this device onto the bare end of a conductor. Wire nuts do not require tape if the conductor ends are cut short enough to prevent them from extending outside the nut.

A wire nut is but one type of solderless connector. Another type is shown in figure view B of figure 8-28. It grips the wires like a vise, producing such good metal-to-metal contact that it is unnecessary to use solder. Apply the connector to the wires, and then cover the joint with tape. Of course, you must prepare the wire ends just as you would for a soldered splice.

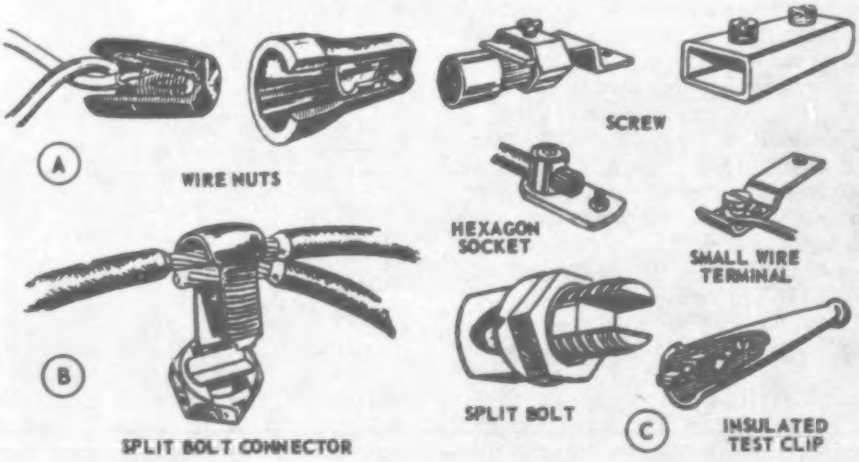
When installing Romex or BX, make sure the conductors do not come in contact with metal pipes, and see that they are supported properly, with no sag between supports. Exposed wiring in basements or attics is best protected by running the wire alongside joists or rafters. Where wires run across these timbers, you can run them through holes bored in the timbers. However, figure 8-29 shows how wire can be run across timbers on a running board.

Flexible cords on portable equipment must never be subjected to mechanical strain. They must be kept as short as possible. All cords must be 3-wire, with the third wire grounding the equipment on one end and terminating at the grounding screw in a 3-wire grounding attachment plug.

MOTOR BRANCH CIRCUITS

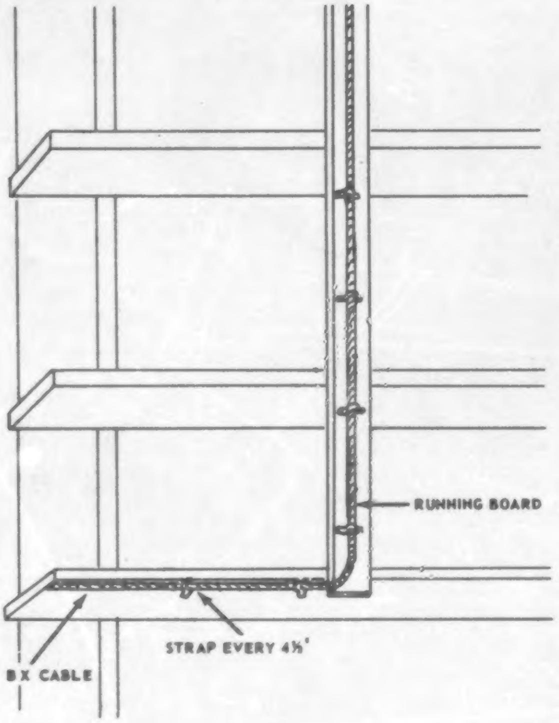
As a CE you will frequently have occasion to wire in, connect, and service motors of various sizes and voltages. A motor branch circuit consists of the following elements: circuit conductors, overcurrent protective devices, means for disconnection, controller, and motor running protection.

The circuit conductors are the wires from panelboard to motor. Overcurrent protective devices protect the motor, controls, and wires against any overloads caused by grounds or shorts. The means of disconnection separates motor and controls from electricity source when adjustment, maintenance, or repair work is being done. The controller starts, stops, and reverses



73.305

Figure 8-28.—Cable and wire connectors.



73.23
Figure 8-29.—Wires run across timbers on a running board.

the motor. Motor running protection is provided by overcurrent protective devices which protect motor, controls, and wires against damage caused other than by grounds and shorts

The circuit conductors may be feeding current to a motor of less than 1 hp. or to one with hp in the hundreds. The type of insulation used will depend on moisture and temperature conditions, and also on the danger of mechanical injury. The size of conductor will be determined on the basis of 125 percent of the full-load current of the motor. Table 8-1 gives you an idea of the wire size for a given motor hp and a given voltage.

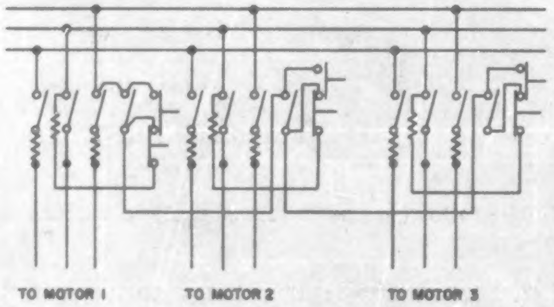
The disconnecting means for most motors is either a motor circuit switch or an air circuit breaker. It must be located within 50 ft of and visible from the motor, and must be equipped with a device for locking in OFF position. In every case the disconnecting device must be one which opens all ungrounded conductors instantly. It may also open the grounded wire, provided that it opens all wires simultaneously. It must disconnect both motor and controller, and may be installed in the same case with the controller.

For portable motors, the attachment plug and receptacle are sufficient means for disconnection. For stationary motors of 1/8 hp or less, the branch circuit overcurrent device is sufficient.

Motor controllers may be manual or automatic. For smaller motors a general-purpose switch or circuit breaker may be used. For larger motors and three-phase motors, automatic controllers give better service. An automatic controller can be remotely controlled by pushbutton, and for machinery motors the pushbutton can be installed convenient to the operator's station. This type of connection can also be used to interlock different motors, as in a system of conveyor belts. Figure 8-30 shows an interlocking system for three motors. Motor 1 must be running before motor 2 can be started, and motor 2 must be running before motor 3 can be started.

Overcurrent protection devices may be fuses or circuit breakers, used to protect the conductors against overloads of current greater than normal starting current. These devices also protect the motor controller, which cannot handle amperage higher than that which is normal for the motor.

If fuses are used, one must be placed in each ungrounded wire of sufficient ampacity to



73.31
Figure 8-30.—Interlocking controls for three motors.

allow for motor starting current. A device other than a fuse must be capable of opening all ungrounded wires feeding a circuit.

MOTOR overload protection is required to protect against overload caused other than by a short or ground in the motor branch circuit. After a motor has come up to full speed, and is operating at its normal rated amperage, the equipment driven by the motor, because of a temporary overload or some other cause, may require more power than the rated hp of the motor. To deliver this extra power, the motor must consume greater-than-normal amperage. This type of overload can be safely carried for a short interval, but if it continues too long the motor will be damaged.

For example: Suppose something causes a fuse in a three-phase circuit to blow. The motor will try to continue running on a single phase. This will cause a much higher than normal amperage to flow through conductors and controller. However, a motor current protection device in the motor or controller will open all conductors to the motor.

Automatic controllers have such a device built into the controller. Some small motors have overload devices built into the motor.

INTERIOR WIRE SPLICES

The way you splice or join conductors together is one indication of your competency as an electrician. An electrical system is only as good as its worst splice. A good splice must have the same mechanical strength and electrical conductivity as the wires it joins together. A spliced wire must be as good a conductor as a continuous wire.

The best wiring practice is to run continuous wires from the service box to the outlets. UNDER NO CONDITIONS SHOULD SPLICES BE PULLED THROUGH CONDUIT. SPLICES MUST BE PLACED IN APPROPRIATE ELECTRICAL BOXES.

The following observations apply to electrical soldering:

1. Soldering a splice helps to protect it from corrosion.

2. Rosin is the only flux used in soldering electrical connections.

3. You can use either a soldering copper or a direct flame to sweat the solder to a splice. Small-sized wire is best soldered with a copper. Large-size requires a blowtorch or an alcohol torch.

Always remember in soldering that you will never get the solder to stick unless the splice itself is hot enough to melt the solder. To determine when the splice is hot enough. However, hold the solder to the side of the splice OPPOSITE the soldering copper. When the solder melts, the splice is hot enough, and the solder will then flow into every crack and hidden space. Figure 8-31 shows wrong and right ways of soldering a splice.

Refer to chapter 7, Basic Electricity, NAVPERS 10068-B and Tools and Their Uses, NAVPERS 10085-B for further information regarding soldering and splicing.

REPAIRS AND MAINTENANCE

Maintenance of buildings is necessary to prevent fire and electrical hazards caused by

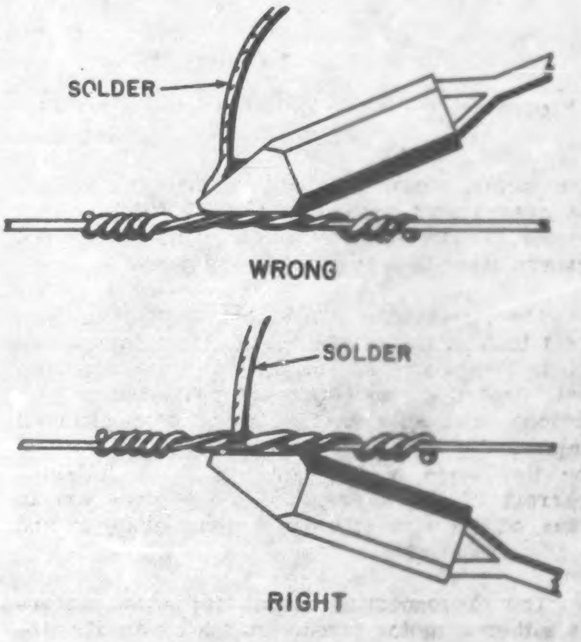


Figure 8-31.—Right and wrong ways of soldering a splice.

defective wiring and equipment. The information below provides guidance for the maintenance of interior electrical systems of 600 volts or less. This includes such components as wiring, disconnecting devices, overcurrent protective devices, panelboards, feeders and illumination.

WIRING SYSTEMS

Loose wires, poor connections, bare conductors, defective convenience outlets and switches, defective attachment cords, and other unsafe conditions should be checked for and corrected when inspecting interior wiring. Rigid steel or aluminum conduit should be used in hazardous areas or where mechanical protection of wiring is necessary. The type of wiring provided should be in accordance with Navy specifications and the National Electrical Code.

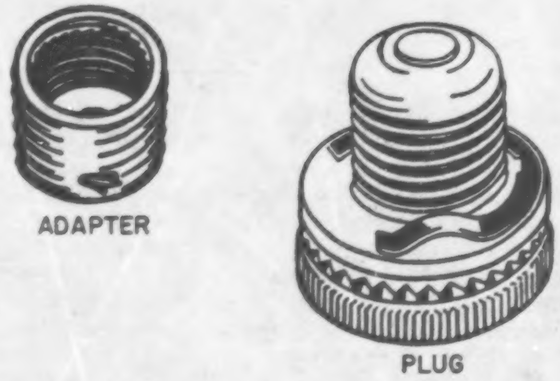
DISCONNECTING DEVICES

Panel connections made by bolts, screws or clamps should be tightened. Loose or poor connections are trouble sources and present a fire hazard. Properly made connections seldom loosen unless subjected to severe vibration.

Partially closed switches may result in burned contacts. Switches should be closed with one rapid motion so the blades are thrown completely into the clips or jaws of the switch. If the switch is tight or the contact is too stiff, monoxide grease on the blades will help close the switch.

FUSES

Fuses commonly found in interior wiring panels are plug fuses or cartridge fuses. Plug fuses are rated from 1 to 30 amperes. The base contact is the same size as a medium-size lamp. This type of fuze has a clear mica window to show the fuse link or some other means of indicating defective fuse link. A disadvantage of the ordinary plug fuse is that a penny or strip of metal may be placed in the fuse receptacle and held in place with a blown fuse to complete the circuit without giving fuse protection. One type of tamper-resisting base fuse uses an adapter that screws into the fuse receptacle and locks into place (fig. 8-32). The fuse, in turn, screws into the adapter. The adapter and fuse plug prevent using a 16 to 30 ampere plug fuse in a 0 to 15 ampere adapter, limiting the possibility of overfusing. Bridging a defective fuse is also practically impossible. Circuits supplying electric motors are subject to the momentary high current required for motor starting and which blows the ordinary fuse providing normal protection. Timelag fuses are used on these circuits. These fuses are available with regular screw bases or tamper-resisting screw bases. The internal construction of the timelag fuse is shown in figure 8-33. The heavy fuse link does not open quickly on motor starting currents. An overload heats the thermal control in the fuse link causing the solder to soften and release the spring at the end of the fuse link (fig. 8-33, view 1). Since motorstarting currents do not last long enough to melt the solder, the timelag fuse does not open. In case of a short circuit, however, the fuse link blows just as an ordinary fuse (fig. 8-33, view 2).



73.413
Figure 8-32.—Plug fuse with tamper-resisting base.

Two kinds of cartridge fuses, ferrule and knifeblade, are shown in figure 8-34. Knifeblade cartridge fuses with nonrenewable, renewable and timelag features are shown in

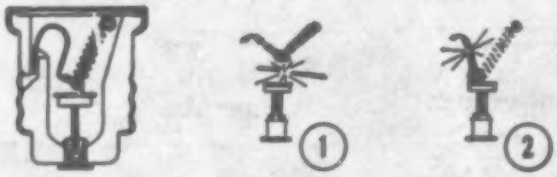


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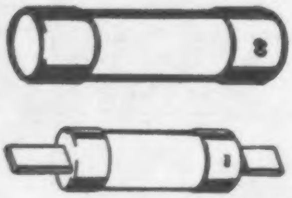
Figure 8-33.—Plug fuse with time lag.



73.415

Figure 3-34.—Cartridge fuses.

figure 8-35. The checklist below should be followed when installing or replacing cartridge fuses and blocks:

1. Check the fuse block to make sure the clips are making full contact with the fuse (fig. 8-36). Improper contacts cause fuses to overheat and may blow at less than rated current. Any prolonged overheating would destroy the fiber case and take the spring tension out of the clips.

2. Replace the clips that have lost their spring or use clip clamps (fig. 8-37).

3. If the inside of the clip is not bright and clean, brighten it with emery cloth.

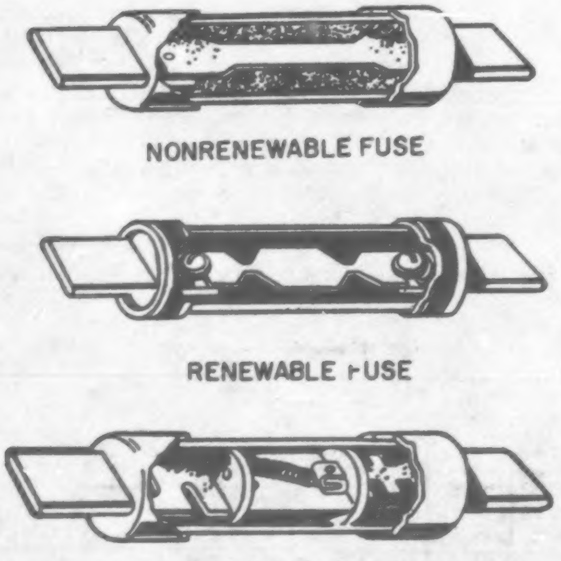


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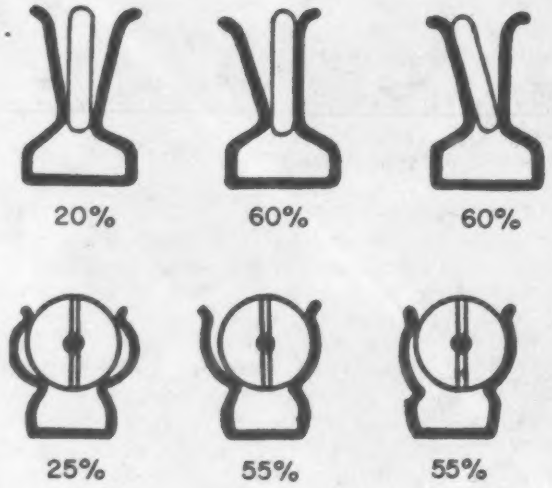
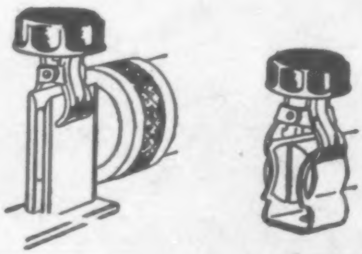
Figure 8-35.—Knifeblade cartridge fuses.



73.417

Figure 8-36.—Poor contact between clips and fuses.



73.418

Figure 8-37.—Clip clamps.

4. If the fuse does not require considerable pressure to insert it into the clips, insufficient contact pressure is present. Remove the fuse and draw clips together. If enough contact pressure is not obtained, replace the clips or use clip clamps.

5. To test for the degree of contact, insert the fuse in the clips and try to insert a thin strip of paper between the clips and the blade or ferrule. If paper can be inserted for a short distance, contact is insufficient and the condition must be corrected.

6. Poor contact at any point on the fuse block is just as bad as poor contact in the fuse or clips. Be sure the lugs are properly soldered

to wires or cables, that the bolts holding the lugs to the fuse block are drawn tight, and that the screws holding the clips to the fuse blocks are tight. Any excessive heating caused by poor contact is transmitted to the clips and fuse, destroying the spring tension of the clips and the fiber tube of the fuse.

7. Check the fuse blocks to make certain that the clips are straight and in line. If the fuse blades are twisted diagonally or bent out of line, the condition caused by damaged or misaligned clips has not been corrected.

A block having one straight and one bent clip is not improved by a fuse with one blade twisted diagonally. Contact in both clips is ruined because the twisted blade must be pushed over, causing both blades to be set into the clips at an angle.

A block with one clip out of line does not permit enough contact even though the blades may be bent out of line, because the angle of one blade is not in line with one of the clips. If the fuse is pushed into such clips, little contact is obtained, because the bent blade must be pushed over to get it into the clip, causing both blades to be set at an angle.

In replacing a blown fuse, keep in mind the following pointers:

1. Do not put in a new fuse until the source of trouble is located and corrected.

2. Do not replace a blown fuse with one of higher rating before determining the carrying capacity of the circuit. Using a fuse too large does not give adequate protection.

3. Do not insert fuses on a live circuit because the circuit may arc. Arcing causes a burr on the ferrule or terminal, which prevents good contact in the clips.

4. If the inside of the clip or contact of the fuse is not bright and clean, brighten it with emery cloth.

In case of a blown fuse, a check of the following conditions will aid you in locating the source of trouble:

1. Portions of the fuse making good contact will be clean and bright. When contact is poor, air gets into the contact surface and heating of the fuse causes oxidations, resulting in discoloration of surfaces. No matter how much a fuse is heated, little oxidation occurs if good contact exists.

2. When only one end of the fuse has a badly oxidized contact surface, poor contact positively existed at the end where the discoloration occurred. Oxidation of the bottom contact on a plug-type fuse indicates poor contact because the fuse was not screwed down tight.

3. If the washer or end ring on a ferrule-contact fuse is burned or partially melted, the cap was not screwed down tight.

4. Charred ends of the fiber tubes on nonrenewable or renewable fuses always indicate poor or inadequate contact (see fig. 8-38). The poor contact may be caused by abuse or lack of proper attention to fuse clips and fuse blocks. When only one end of the fuse is charred, poor contact existed at the charred end.

5. Charred ends of the fiber bar of a renewable fuse always indicate poor contact even though the fiber tube is not already charred. If poor contact is continued, the fiber tube is also sure to char.

6. Figure 8-39 illustrates fuse links blown under four different conditions. The first is a result of poor contact; the blow is between the reduced portion and the end of the link. The second is a normal blow when contact was good; the third is also normal, indicating a light overload. The fourth shows the result of heavy overload or short circuit.

7. Figure 8-40 shows blown links in nonrenewable fuses. When break occurs in center,

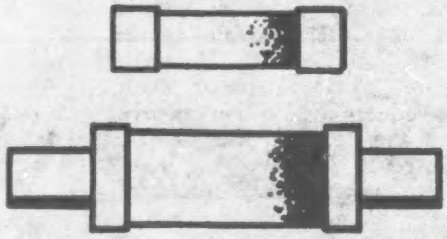


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Figure 8-38.—Charred fiber tubes.

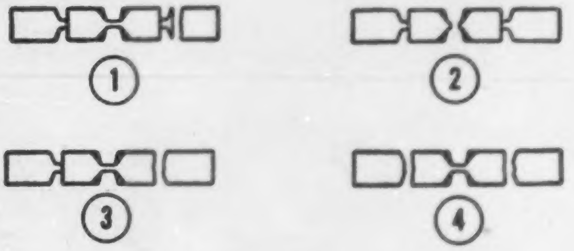

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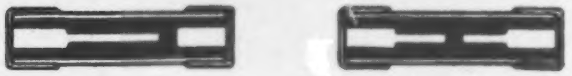
Figure 8-39.—Fuse links blown under various conditions.



73.421
Figure 8-40.—Blown links in nonrenewable fuses.

a good contact is indicated. Break at one end is usually caused by poor contact.

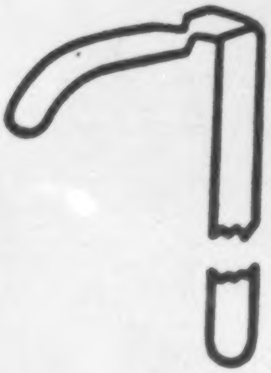
8. A plug-fuse link blown as shown in figure 8-41 indicates a poor contact and is usually accompanied by discoloration of the bottom contact. The blow should come at the center or upper portion of the link.

OVERLOADS

An overload occurs when the electric load becomes greater than the safe carrying capacity of the wiring or apparatus. It is usually indicated by frequent blowing of fuses or tripping of circuit breakers and abnormally hot wiring or equipment. When an overload appears likely, the load should be checked with an ammeter to determine the actual ampere load. An apparent overload may be caused by a partial ground on the circuit. Partial grounds should be located by ohmmeter or insulation resistance testing equipment. When an overload is found, part of the load should be transferred to another circuit or the wiring should be increased in size to provide adequate capacity.

LOAD BALANCE

An unbalanced load may result in heating of the wiring and panelboards and blown fuses or tripped breakers. An unbalance occurs when one side of a 3- or 4-wire circuit has a greater load than the other (fig. 8-42). This can be readily checked by using a clamp-on ammeter and taking ampere readings when the circuits are loaded. Unbalance can be corrected by changing part of the connected load from the overloaded side to the lightly loaded side. If this is not practical, part of the load may be transferred to another circuit, or a new circuit installed.



73.422
Figure 8-41.—Blown link in plug fuse.

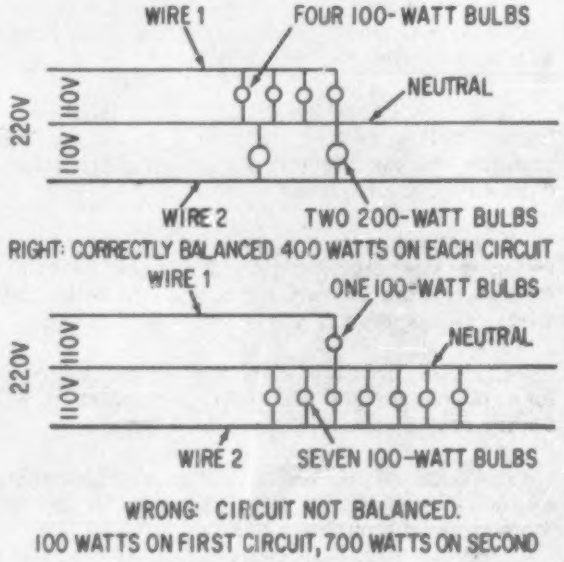

WIRE 1
FOUR 100-WATT BULBS
NEUTRAL
220V
110V
110V
WIRE 2
TWO 200-WATT BULBS
RIGHT: CORRECTLY BALANCED 400 WATTS ON EACH CIRCUIT
WIRE 1
ONE 100-WATT BULBS
NEUTRAL
220V
110V
110V
WIRE 2
SEVEN 100-WATT BULBS
WRONG: CIRCUIT NOT BALANCED.
100 WATTS ON FIRST CIRCUIT, 700 WATTS ON SECOND

Figure 8-42.—Load balancing. 73.423

OPEN CIRCUITS

An open circuit exists when one or more conductors in a circuit are broken, burned open, or otherwise separated. Part or all of the lights will be out and the equipment will not operate even though the fuse has not blown nor the circuit breaker opened (see fig. 8-43).

When an open circuit occurs, check at the least energized outlet on the circuit for broken or loose connections. If a defective connection is found, repair and splice it out or install new wire as necessary.

If the trouble is not visible, use a test lamp to trace the circuit back to the source (fig. 8-44).

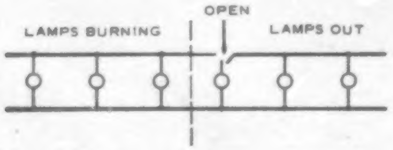
NOTE: For 110-volt motors, use a single bulb rated from 110 to 130 volts. For 220-volt motors, use one 220-volt bulb or two 110- to 130-volt bulbs in series.

SHORT CIRCUIT OR GROUND

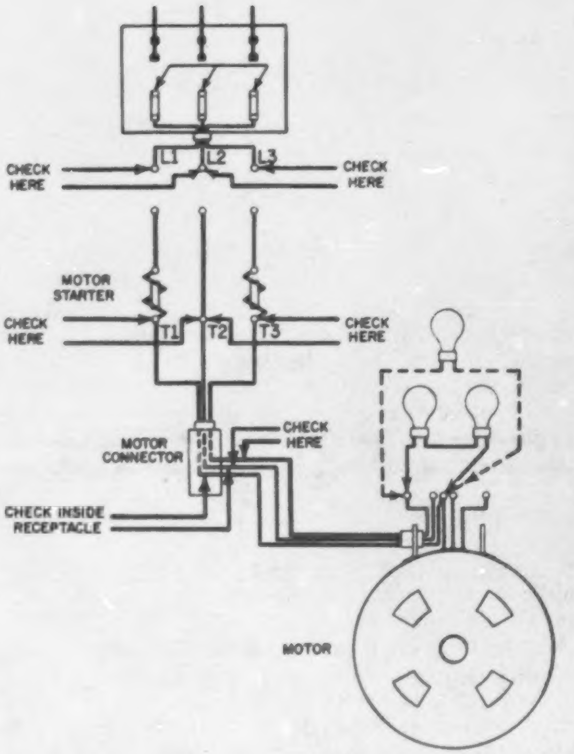
A short circuit results when two bare conductors of different potential come in contact with each other. If a hot conductor is making contact with some metallic part of the wiring system, such as the conduit (fig. 8-45) or a motor frame connected to ground, it is called a ground. A high resistance ground may cause current flow without opening a breaker or blowing a fuse.

To determine the cause and location of trouble in a building wiring circuit, protected by plug fuses, the following procedure is suggested:

Make sure the circuit is not overloaded. Then remove the blown fuse and screw a 200-watt lamp into the fuse receptacle. If the lamp burns at full brilliancy with the neutral open, the circuit is grounded. If the lamp burns with the neutral closed and goes out when the neutral is opened, a short circuit is indicated.



73.424
Figure 8-43.—Open circuit with part of lights out.



73.425
Figure 8-44.—Using a test lamp at various points in a motor circuit to locate a line break.

If a short circuit exists, leave the 200-watt lamp in the fuse receptacle to prevent the flow of excessive current. If the trouble is not discovered by a quick visual inspection, pull out the plugs of all portable equipment on the circuit and turn off all wall switches. If the short circuit is cleared during this isolation process, the lamp in the fuse receptacle will go out or glow dimly. Do not leave the 200-watt lamp in the receptacle after insulating the defective device. Leaving the lamp in the receptacle will create a low voltage condition. If certain loads—for example, motors—are connected, they could be seriously damaged by the low voltage.

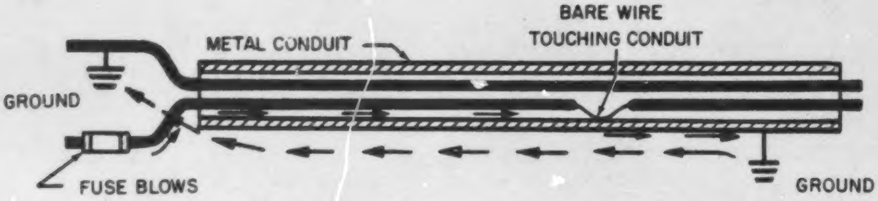


Figure 8-45.—Wire grounded by conduit.

If the 200-watt lamp in the fuse receptacle continues to burn after all the load is disconnected, install a test lamp in the nearest convenience outlet on the circuit. Open the circuit at various outlet points and observe the lamp. When the faulty section of the circuit is disconnected, the test lamp will burn dimly.

LIGHTING SYSTEMS

Each lighting installation is designed to produce a specific level of illumination adequate for those working in the area. The amount of illumination initially provided starts to decline almost as soon as it is put in operation. This reduction is caused by dirt on the lamps and luminaires, a decrease in lamp lumen output, and dirt on the room walls and ceilings. Illumination should be sufficient to eliminate eyestrain, maintain a high level of production, and promote safety and employee morale.

Incandescent Lamps

Lighting fixtures are designed for a particular lamp size and type. Many fixtures, however, were installed in military buildings long before the manufacturers started producing higher and higher wattage lamps in ever smaller envelopes. Consequently, it is possible to use much higher wattage lamps than the fixture or the circuit can handle adequately. Excessive heat of higher wattage lamps can damage the sockets, increase failure rate, and overload the circuits. Personnel are cautioned to use only the lamp size (in watts) recommended for the fixture rather than a higher wattage lamp that may physically fit.

Incandescent lamps come in a variety of voltage ratings. For most applications, the lamp voltage rating nearest the available line voltage should be selected. Under this condition, the lamp will produce its rated values of life, watts, and light output. Many incandescent lamps are available with life ratings considerably in excess of ordinary general service lamps. Some have ratings of 5,000 hours or more and some even are guaranteed to burn for 5 years. Use of these lamps is not recommended because the initial cost is comparatively high and the extended life is gained by reducing the light output. There are, however, a few areas where it is necessary to use bulbs with a long life. Typical locations include high ceiling auditoriums, exit lights, stairwells, and marker lights on towers or fire alarm boxes. For these areas, do not use a special rated lamp. Do use an ordinary general service lamp whose voltage rating is higher than the circuit voltage, e.g., 130-volt or higher lamps for 120-volt circuits. By operating the lamp below its rated voltage, the life is increased at a sacrifice in light output. For general use, the lamp voltage rating nearest the available line voltage should be used.

There are many kinds of incandescent lamps especially designed for placement in variety of situations; for example, under severe physical conditions (such as vibration or extreme temperatures), in inaccessible locations or when special lighting effects are desired. Some of these types of incandescent lamps and their uses are:

INSIDE-FROSTED LAMPS are used in most fixtures designed for incandescent lamps. The frosted finish reduces lamp brightness and glare.

CLEAR LAMPS are used in fixtures where control of the light is required (such as in reflectors having polished reflecting surfaces and in enclosed gloves or reflectors of prismatic glass), particular where concentrated light control is required, as in high narrow bays.

Reflector equipment of the diffusing globe type, where the lamp protrudes through the bottom of the fixture, requires WHITE BOWL LAMPS. The white bowl reduces the surface brightness and glare from the working surfaces.

SILVERED-BOWL LAMPS are used principally for indirect lighting and in reflector equipment. The fixture parts should not touch the lamp as the thermal expansion may cause the bulb to crack and fail prematurely.

REFLECTOR LAMPS, with the reflecting surface inside the lamp are, in effect, a fixture in themselves. The lamps can lose their effectiveness due to the collection of dust and dirt on the exterior.

PROJECTOR LAMPS are installed in indoor and outdoor display lighting fixtures. They employ a self-contained reflector but have advantage over the reflector type since they are suitable for extreme temperature conditions and provide more accurate light control.

HEAT AND DRYING LAMPS, available with built-in reflectors or with separate reflectors, are an inexpensive answer to a requirement for instantaneous infrared energy. The reflector bulb keeps the initial cost to a minimum and provides a new reflecting surface with each new lamp.

HARD-GLASS LAMPS, made of special glass with high resistance to thermal shock, are effective where rain, splashing liquids, insects, snow, fixture parts, or hot metallic spray may touch the glass bulbs.

VIBRATION SERVICE LAMPS are available that withstand excessive vibration which cannot be eliminated by flexible fixture mounting.

Where the lamp will be subjected to shock, such as at the end of a drop cord or near machinery, you will want to select ROUGH SERVICE LAMPS. With filament supports, these lamps can withstand severe shocks without failure.

High-cost replacement areas such as towers, industrial high bays, theater marquees, halls, and stairwells are lighted with LONG-LIFE LAMPS.

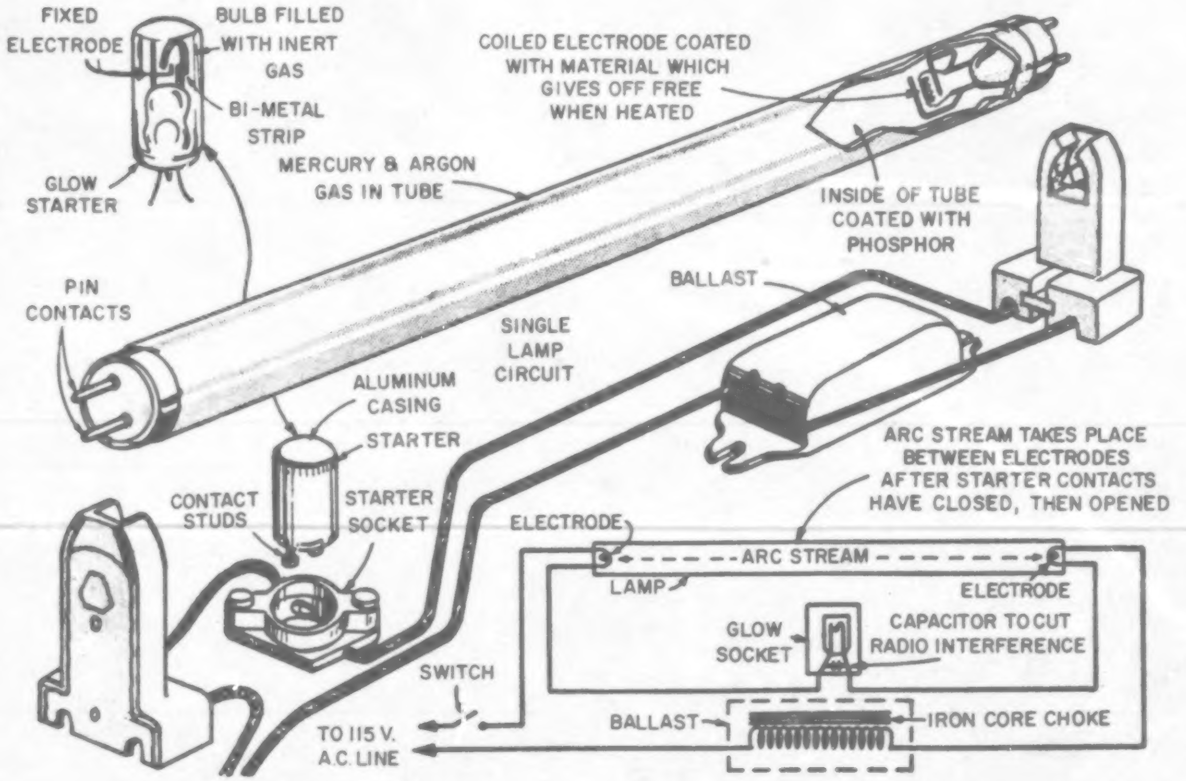
QUARTZ-IODINE LAMPS offer a very concentrated source of incandescent light with excellent light control characteristics, good color, and a life twice that of regular general service incandescent lamps. They depreciate at a lower rate than the general service lamp. The lamp cost is considerably higher, however, than a general service lamp, and a special fixture is required.

Fluorescent Lamps

There are two principal types of fluorescent lamps, instant-start and rapid-start preheat lamps. Both have practically the same physical dimensions but different internal construction. The type of circuit in which the lamp should be used is etched on the end of the lamp. The rapid-start preheat lamp operates satisfactorily with either the preheat or rapid-start circuits. It has a very short lamp life in an instant-start circuit. The instant-start lamp operates satisfactorily with an instant-start ballast, burns out the ballast in a rapid-start circuit, and does not light in a preheat circuit. Preheat lamps dominated the field for many years but are no longer considered a major type. They continue to be in use, however, particularly in fixtures using lamps smaller than 40 watts. A typical preheat circuit is shown in figure 8-46. Other examples of circuits for the major types are readily found in current manufacturers' publications. An example of some circuits is shown in figure 8-47. The 4-foot rapid-start lamp is the preferred lamp for most applications.

Fluorescent lamps are available in a variety of colors for decorative use as well as numerous shades of white for general illumination. The predominant white shade recommended for most office areas is Cool White. Other shades of white used for various purposes include Daylight, Deluxe Cool White, White, Warm White, and Deluxe Warm White. Daylight and Cool White provide a crisp, cool, business-like atmosphere and the warm whites find application in restaurants, homes, theaters, and similar areas. Colored materials will appear more favorable under a fluorescent light that contains a high component of the same color. Blue backgrounds improve with the cool whites and daylight. Deluxe warm whites flatter reds while white and warm whites strengthen oranges and yellows.

Fluorescent lamps require ballasts to limit the current and to supply proper voltage to start and to operate the lamps. For general lighting purposes, the ballasts also contain a


FIXED ELECTRODE
BULB FILLED WITH INERT GAS
BI-METAL STRIP
GLOW STARTER
COILED ELECTRODE COATED WITH MATERIAL WHICH GIVES OFF FREE WHEN HEATED
MERCURY & ARGON GAS IN TUBE
INSIDE OF TUBE COATED WITH PHOSPHOR
PIN CONTACTS
BALLAST
SINGLE LAMP CIRCUIT
ALUMINUM CASING
STARTER
CONTACT STUDS
STARTER SOCKET
ARC STREAM TAKES PLACE BETWEEN ELECTRODES AFTER STARTER CONTACTS HAVE CLOSED, THEN OPENED
ELECTRODE
ARC STREAM
LAMP
ELECTRODE
GLOW SOCKET
CAPACITOR TO CUT RADIO INTERFERENCE
SWITCH
BALLAST
IRON CORE CHOKE
TO 115 V. A.C. LINE

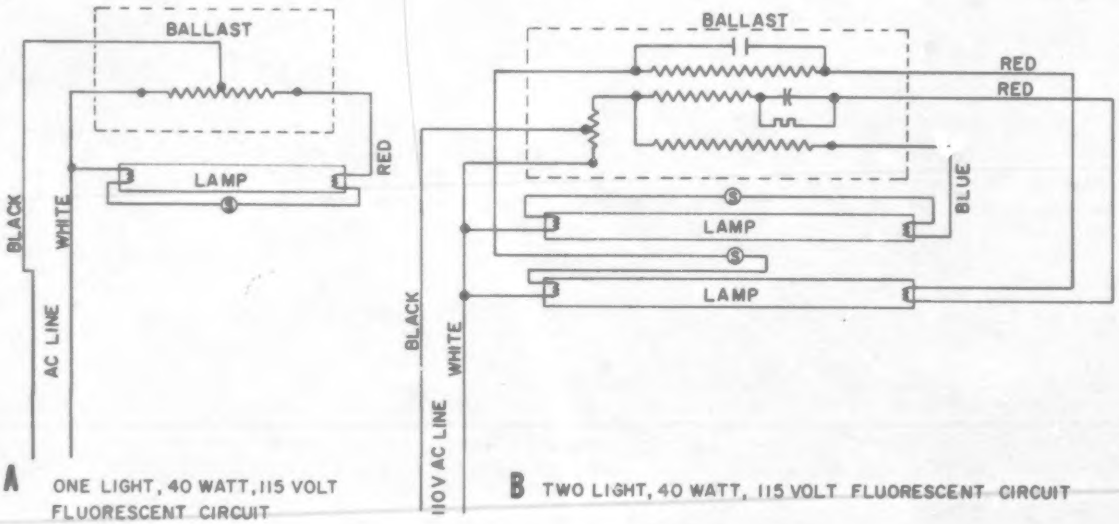
73.427

Figure 8-46.—Preheat fluorescent lamp and circuit.

capacitor to improve power factor. The current National Electrical Code requires that all indoor fluorescent fixtures (except those with simple reactance ballasts) must incorporate ballasts with thermal protection. The thermal protector isolates the ballast (and fixture) from the circuit in the event of overheating. As a result, damage from fires and from leaking compounds should be reduced. There are small fuses available that can be installed in the fixture to provide this protection for existing ballasts.

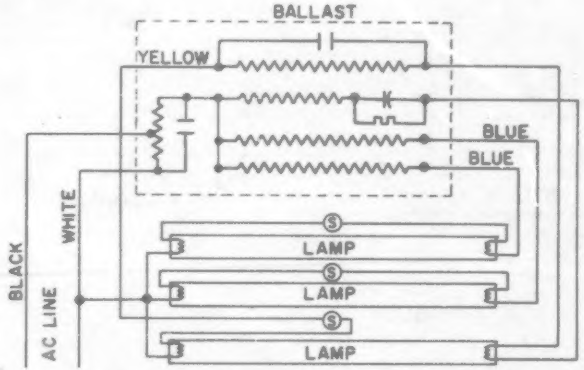
Mercury Lamps

Mercury lamps (fig. 8-48) have the best maintained light output because the electrodes operate at a relatively cool temperature resulting in less evaporation of the metals and oxides. The clear mercury lamp has a better lumen maintenance than those with phosphor coating. Long average life (16,000 hours and up) is a primary characteristic of most mercury lamps. There will be a different economic life for mercury lamps at each installation depending on lamp mortality, power cost, equipment and wiring costs, frequency of replacement and cleaning of lamps, and other factors. Mercury lighting is one of the most economical means of lighting high- and medium-bay industrial areas, particularly in areas where color rendition is not critical. Small wattage lamps have been introduced, and it is anticipated that future designs will see a more widespread use of these in low-ceiling nonindustrial areas. While the lamp bases are the same size as incandescent lamps, mercury lamps must never be used to replace a burned-out incandescent lamp because a ballast must be used with mercury lamps. An objectionable characteristic of mercury lamps is the time required to reignite (several minutes) after a momentary loss of power.


BALLAST
LAMP
RED
BLACK
WHITE
AC LINE
BALLAST
RED
RED
BLUE
LAMP
LAMP
BLACK
WHITE
110V AC LINE

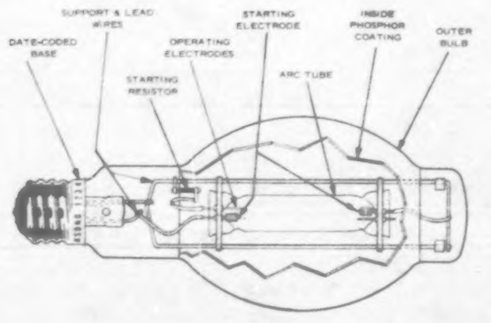
A ONE LIGHT, 40 WATT, 115 VOLT FLUORESCENT CIRCUIT

B TWO LIGHT, 40 WATT, 115 VOLT FLUORESCENT CIRCUIT


BALLAST
YELLOW
BLUE
BLUE
WHITE
BLACK
LAMP
LAMP
LAMP
AC LINE

C THREE LIGHT, 40 WATT, 115 VOLT FLUORESCENT CIRCUIT

Figure 8-47.—Representative fluorescent circuits. 73.35


SUPPORT & LEAD WIRES
STARTING ELECTRODE
INSIDE PHOSPHOR COATING
OUTER BULB
DATE-CODED BASE
OPERATING ELECTRODES
STARTING RESISTOR
ARC TUBE

73.428

Figure 8-48.—Mercury lamp.

Metallic-Vapor Lamps

Metallic-vapor lamps resemble mercury-vapor lamps in appearance and have similar uses. The initial efficiency and control are better with metallic-vapor lamps than with mercury-vapor lamps. In regard to disadvantages, the rate of depreciation is much greater with metallic than with mercury, the cost is higher, and the life expectancy is shorter.

High-pressure sodium-vapor lamps are used for highway interchanges, parking lots, and high-bay industrial areas. They are the most efficient of the light sources in general use in number of lumens produced per watt of electricity. The relative cost is high, the life ratings are not well established, and a special ballast is required. The color is slightly yellowish.

Overall Illumination

Walls, ceilings, and surroundings are an important part of the overall illumination system since they redirect light to the working area. The most efficient lighting system is obtained when the fixtures are new and when the walls, ceilings, floors, and furnishings of the room are colored with a high reflectance color. Lighting is, however, only one of many factors that make up the whole environment. While the highest lighting efficiency may be maintained in a completely white room, the psychological effect of such surroundings on the occupants may be less than harmonious. The use of color in the surroundings, even if it means sacrificing lighting efficiency, is necessary for the well-being of the occupants. Ceilings should have the lightest color, preferably an off-white. Shiny surfaces should be avoided as they result in glare. As mentioned earlier, lighting levels start dropping immediately after the installation of the fixtures. Lamp burnouts and lamp depreciation contribute to this but the principal cause is the accumulation of dirt. It is not uncommon to find lighting levels 1/2 the initial values after only a year or so of operation. The lighting maintenance program must include cleaning and painting of the walls and ceilings in addition to the fixture cleaning schedule.

TROUBLESHOOTING LAMPS

as light sources are designed to operate most efficiently and economically at their rated voltages, special emphasis should be given to using lamps to suit the voltage of the circuit. Operation within the normal operating range is desirable, because both overvoltage and undervoltage operations have a determined effect on the life, efficiency, and economy of the light source. The effect on lamps operated over or under their rated voltage range is as follows:

FLUORESCENT LAMPS. Line voltage higher than the maximum of the ballast range will shorten lamp and ballast life. Line voltage below the minimum range will reduce illumination and may cause uncertain starting of fluorescent types.

INCANDESCENT LAMPS. Line voltage higher than the maximum lamp range will increase the light output but will shorten lamp life. Line voltage below the minimum range will extend lamp life but will reduce light output approximately 3 percent for each 1 percent in voltage drop.

MERCURY LAMPS. Line voltage higher than the maximum lamp range will shorten lamp and ballast life. Line voltage below the minimum range will reduce illumination and may cause uncertain starting.

LAMP GUIDES. The most common troubles encountered with lamp equipment, the probable causes, and the suggested solutions are contained in table 8-2.

MAINTENANCE

Lighting has a great influence on the quality and quantity of work as well as a direct bearing on employee morale. The necessity for periodic attention to the lighting system cannot be overemphasized. To prevent progressive deterioration of the system, regular maintenance and prompt repair of any deficiency are essential.

Maintain the required illumination intensity by keeping lamps, fixtures, and reflective areas clean and in good repair; replacing defective lamps; and keeping the voltage steady.

It is well-known that dirt absorbs and masks light. The progressive decrease of light caused by accumulating dirt renders periodic cleaning of lighting equipment a necessity. The frequency of cleaning depends largely upon local conditions. Fixtures in air-conditioned and air-filtered rooms may require cleaning only once a year. In an atmosphere which is heavy with dust and fumes, cleaning every few weeks may be necessary.

The cleaning schedule for a particular installation should be determined by light meter readings after the initial cleaning. When subsequent foot-candle readings have dropped 20 to 25 percent, the fixtures should be cleaned again. Readings should be made with the light meter at the working surface with the meter reader in the position of the operator or person using the working surface.

Table 8-2.—Lighting maintenance chart

INCANDESCENT

SYMPTOM	POSSIBLE CAUSE	REMEDY
LAMP OUT, BUT NOT DEFECTIVE	LOOSE LAMP, OR LOOSE OR BROKEN CONNECTIONS.	TIGHTEN IN SOCKET, OR SECURE TERMINALS, OR REPAIR WIRING.
LAMP BURNS DIM	LOW VOLTAGE.	MATCH LAMP RATING TO LINE VOLTAGE. INCREASE LINE VOLTAGE.
SHORT LAMP LIFE	HIGH VOLTAGE, OR BULB CRACKED, OR INCORRECT LAMP, OR EXCESSIVE VIBRATION.	MATCH LAMP RATING TO LINE VOLTAGE AND REDUCE VOLTAGE. REPLACE LAMP. REPLACE WITH LAMP OF PROPER RATING. USE SHOCK-ABSORBING DEVICE.
LAMP BREAKAGE	WATER CONTACTS LAMP BULB, OR BULB TOUCHES LUMINAIRE.	USE INCLOSED, VAPORTIGHT LUMINAIRE IF WATER VAPOR IS PRESENT. SEAL JOINT WHERE CONDUIT STEM ENTERS LUMINAIRE. USE CORRECT-SIZE LAMP. STRAIGHTEN SOCKET.

FLUORESCENT

SYMPTOM	POSSIBLE CAUSE	REMEDY
LAMP DOES NOT START OR FLASHES ON AND OFF	LAMP PINS NOT CONTACTING, OR LAMP WORN OUT, OR STARTER DEFECTIVE, OR LOW LINE VOLTAGE, OR FAULT IN CIRCUIT OF LUMINAIRE.	SEAT LAMP FIRMLY AND CORRECTLY. REPLACE WITH TESTED LAMP. REPLACE WITH TESTED STARTER. CHECK WITH VOLTMETER. CHECK WIRING AND LAMP HOLDERS. CHECK BALLAST.
NOTE A FLASHING LAMP USUALLY INDICATES END OF LAMP LIFE.		
LAMP FLICKERS; ARC WIGGLES, SWIRLS OR FLUTTERS	DEFECT WHICH OCCURS IN BOTH NEW AND OLD LAMPS.	TURN LUMINAIRE ON AND OFF SEVERAL TIMES. ALLOW A NEW LAMP TO OPERATE A FEW HOURS FOR SEASONING. REMOVE LAMP AND SHAKE ONE END DOWN. REPLACE LAMP IF FLICKER PERSISTS. IF FLICKER IS REPEATED IN NEW LAMP, REPLACE STARTER.
LAMP STARTS SLOWLY *(should start in a few seconds)*	LOW LINE VOLTAGE OR SLOW STARTER.	CHECK WITH VOLTMETER. REPLACE STARTER.
SHORT LAMP LIFE *(A few early failures do not indicate average for group. Some fail after a few hundred hours; others last 4000 - 6000 hours.)*	LOW LINE VOLTAGE, OR LAMPS TURNED ON AND OFF TOO OFTEN.	CHECK WITH VOLTMETER.
RADIO INTERFERENCE	MAY ORIGINATE FROM OTHER SOURCE–RADIO TOO CLOSE TO LAMP–AERIAL LEAD-IN NOT SHIELDED.	OPERATE RADIO WITH FLUORESCENT LAMPS TURNED OFF. MOVE RADIO 9 TO 10 FEET FROM LAMP. SHIELD LEAD-IN AND GROUND SHIELD. INSTALL FILTER RADIO OR LUMINAIRE.
NOISE FROM BALLAST. *(Don't expect perfect silence)*		IF QUIET NECESSARY, TAKE SPECIAL PRECAUTIONS IN LOCATING BALLAST. IF UNIT VERY NOISY, REPLACE BALLAST.

MERCURY LAMP

SYMPTOM	PROBABLE CAUSE	REMEDY
LAMP FAILS TO START	LAMP LOOSE.	TIGHTEN IN SOCKET.
	LAMP BURNED OUT.	REPLACE.
	LOW VOLTAGE.	INCREASE LAMP VOLTAGE BY CHANGING TRANSFORMER TAP.
	WIRING FAULT.	CHECK WIRING. TIGHTEN CONNECTIONS.
	LOW TEMPERATURE.	LAMPS MAY NOT START WHEN TEMPERATURE IS BELOW 32° F.
	FLUCTUATING VOLTAGE.	CHECK LINE VOLTAGE. *(Momentary dips of 10 percent, or more, often cause light to go out.)*
LAMP FREQUENCY GOES OUT	WIRING FAULT.	TIGHTEN CONNECTIONS. CHECK WIRING. SEPARATE LIGHTING CIRCUITS FROM HEAVY POWER CIRCUITS.
ANNOYING STROBOSCOPIC EFFECT	CYCLIC FLICKER.	WHERE THERE IS A 3-PHASE SUPPLY, CONNECT LUMINAIRES ON ALTERNATE PHASES. ON SINGLE-PHASE, ADD INCANDESCENT LUMINAIRES TO THE SYSTEM.

Lighting equipment should be washed, not just wiped off with a dry cloth. Washing reclaims 5 to 10 percent more light than dry wiping and reduces the possibility of marring or scratching the reflecting surface of the fixtures.

To clean removable glassware, reflectors, and diffusing louvers, immerse in a solution of synthetic detergent cleaner and scrub with a soft brush or sponge. When incrustation is not removed by scrubbing, use No. 0 steel wool to remove dirt film. Rinse in warm clear water and dry with a clean cloth.

CAUTION: Do not immerse lamp base or electrical connections in the cleaning solution.

Glassware, reflectors, and diffusing louvers that cannot be removed should be cleaned as follows:

Wipe with a moist cloth or sponge, using a solution of synthetic detergent cleaner. When incrustation is not removed by sponging, use No. 0 steel wool to remove dirt film. Care should be taken to ensure that shreds of steel wool do not touch the pin contacts or get into the lamp socket. Wipe off excess moisture with a clean cloth. Clean fixture holders and stem hangers with a moist sponge or cloth dampened with synthetic detergent cleaner and wipe dry. Enameled, chrome, aluminum, or silver-plated reflecting surfaces that cannot be adequately cleaned and polished should be replaced.

Neglected lamp outages reduce illumination. If burned-out lamps are not promptly replaced, illumination may drop to unsafe foot-candle levels in a short time, due to outages alone. In some cases it may be satisfactory and more economical to clean lamp surfaces and fixture interiors only at the time of relamping. Each activity must determine whether cleaning is to be accomplished by electrical, self-help, or custodial service personnel.

Burned-out lamps are replaced on request. To prevent reduced illumination from lamp outages:

1. Instruct employees to report burnouts as they occur.

2. Replace blackened or discolored lamps even though they are still burning. Discoloration indicates the lamp is nearing the end of its useful life.

3. Replace fluorescent lamps as soon as they begin to flicker. A burned-out lamp in a live circuit may cause damage to starter and ballast. Blackening at the ends of the tube adjacent to the base indicates that the lamp is near the end of its useful life.

4. In general, replace with the same type, wattage, and voltage as that of the lamp removed. If frequent burnouts occur, voltage rating of lamps may be too low. Lamps of higher wattage than called for on lighting design plans should not be used.

CHAPTER 9

CENTRAL POWER STATIONS

Since the days of Faraday, electricity has been generated at various power sources. Waterfalls, coal, and oil have been used as sources for the conversion of their energy into electricity.

At present, hydroelectric, steam-turbine, or internal combustion engine generators at central power stations generate electricity economically and efficiently because of their physical proximity to their sources of power or customers.

Steam turbine generators are utilized on larger Navy shore installations where the prime purpose of the steam is for heating, or aboard steam-driven ships.

Large diesel engines are the kind most of you will encounter other than the portable sets discussed in this chapter. Maintenance and repair of the internal combustion type are relatively easy compared to the hydroelectric and steam turbine generators.

Today nuclear power is looming as a source of electricity. As time goes on, more and more of the electrical energy supplied in the United States will originate from nuclear power.

Especially selected CEs are sent to nuclear reactor schools for special training in nuclear power generation. CEs operate these plants in certain shore installations for the Navy. Thorough knowledge of electrical theory and practical ability are prerequisites for selection for training in the nuclear power field. Study this book and other training material thoroughly if you want to be considered for such training.

As a Construction Electrician you will help in the installation, operation, maintenance, and repair of advanced-base generating equipment. This equipment is portable and ranges in size from 1.5 kw to 600 kw. In time of war or national emergency, portable generator equipment will normally be used at temporary overseas bases. Even in peacetime, portable equipment may be used at remote bases.

Table 9-1.—Family of Engine-Generators

	ALTERNATING CURRENT					
FREQUENCY	60-HERTZ					
VOLTAGE	120		120/208		120/208 240/416	
PHASE	1		1 & 3		3	
WIRES	2		4*		4	
FUEL	G	D	G	D	G	D
KW RATING						
1.5	X					
3			X			
5			X			
10			X			
15					X†	X†
30					X†	X†
45						X†
50					X	X†
75						X†
100						X†
150						X†

G-GASOLINE DRIVEN. D-DIESEL DRIVEN.

† -THESE GENERATORS TO PRODUCE EITHER 50- OR 60-HERTZ.

* -PANEL CONNECTIONS PERMIT, AT RATED KW OUTPUT: 120/208V 3-PHASE 4-WIRE, 120V 3-PHASE 3-WIRE, 120V SINGLE PHASE 2-WIRE, 120/240V SINGLE PHASE 3-WIRE.

26.163

At large, more permanent activities overseas, you may have duties associated with the installation of large electrical power systems.

Generating equipment installed at advanced bases is simple, rugged, and reliable. It is also flexible in that power can be supplied even after part of the plant is damaged. It is up to you to take advantage of these characteristics by learning how to install, operate, maintain, and repair the components of this electric plant and its distribution system.

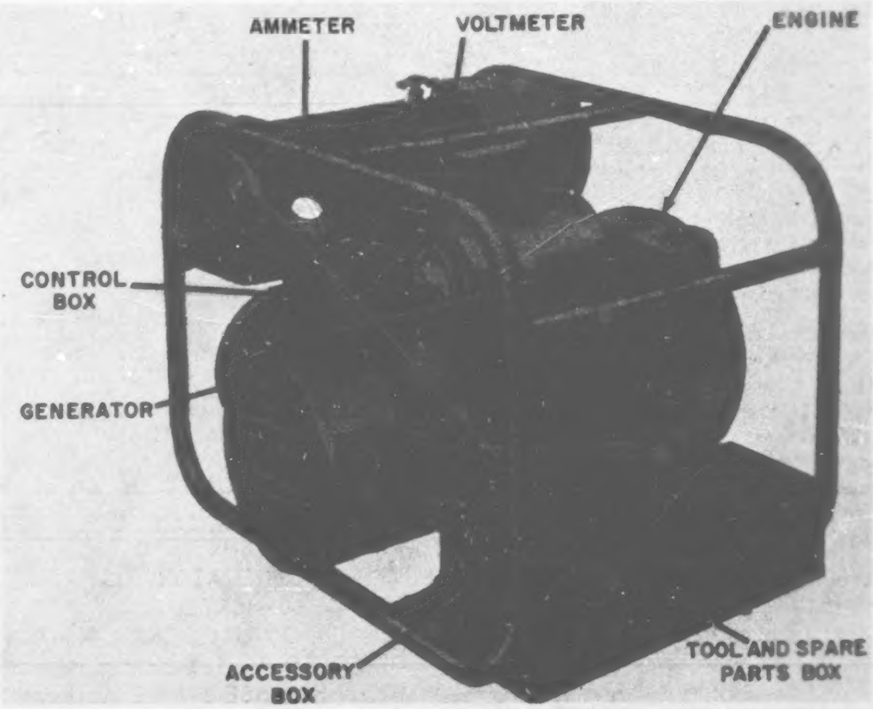
You can learn how by applying the fundamentals of electricity and electronics and by observing a few simple rules and working practices.

GENERATOR EQUIPMENT

When an overseas base is first established, electric power is needed in a hurry; you will not have time to set up a centrally located generating station. Instead, you will spot a portable plant at each important location requiring power. Table 9-1 lists some of the standard alternating current generators available. These standard generators are capable of meeting the power requirements of advanced bases.

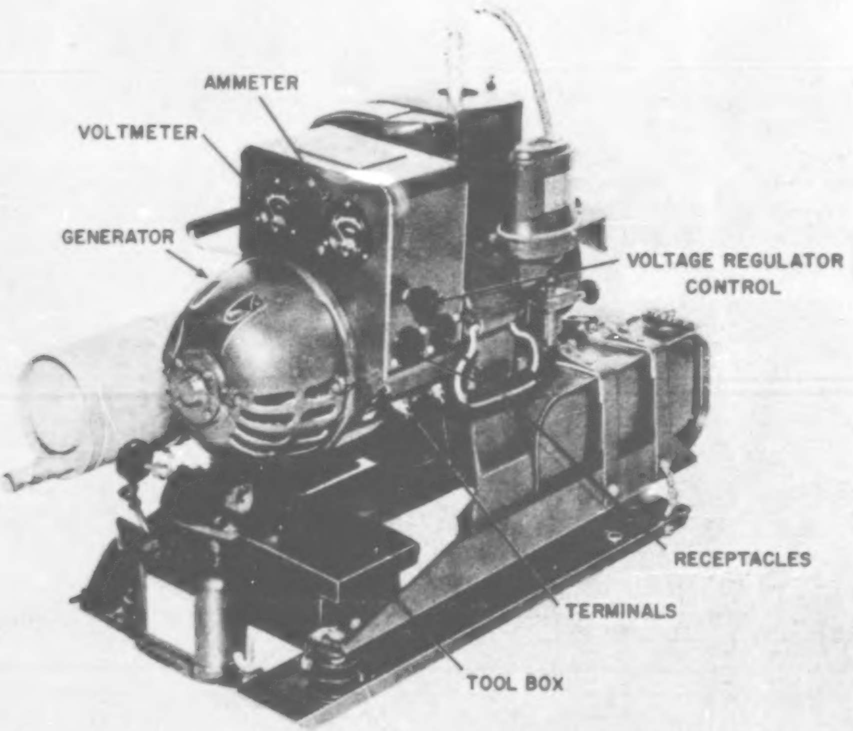
DIESEL AND GASOLINE ENGINE SETS

Both gasoline and diesel engines are useful as prime movers for generators. Diesel engines are used to drive the larger generators (15 kw and higher) because, they are highly reliable in operation, have a low fuel consumption per horsepower per hour, reduced fire hazard, lower maintenance cost and longer useful life than the gasoline engine. Gasoline engines are more suitable to supply power and light on an intermittent or emergency basis. Their initial cost is



73.306

Figure 9-1.—Gasoline engine generator.



26.64

Figure 9-2.—Representative 1.5-kw., 120-volt, 60-hertz, portable generator set.

much less than that of diesel engines, but maintenance costs are higher and their useful life is short.

The one cylinder engine driven generator in figure 9-1 is about the simplest you'll find in an advanced base. It will handle loads up to 1.5 kilowatts. A starting rope wrapped around the flywheel is used to start the engine in the same manner as that for small outboard or power lawn motors.

Some gasoline-driven generators used by the Seabees supply as much as 10 kilowatts of a-c power. These may be used as emergency standbys for a small central power station. They are skid-mounted, and if equipped with weatherproof metal housing, are designed primarily as portable sets for outdoor operation.

GENERATORS

The 1.5-kw output generator delivers 120 volts single-phase at a frequency of 60 hertz. It is a very versatile and widely used small generator because its output is adequate for the communications and lighting requirements for use in the field. Figure 9-2 shows a 1.5-kw generator mounted on a base with handles to make it transportable by two men. The simplicity of operation is evidenced by a single control consisting of a field rheostat or voltage-regulator control to permit adjustment of the voltage output. Representative 10- and 60-kw generators are illustrated in figures 9-3 and 9-4.

The electrical loads to be supplied, power, voltage, phase, frequency and duty cycle requirements govern the selection of generating equipment. Probable load deviation, probable life of the installation, availability of fuels, and availability of skilled personnel are other important factors.

Electrical plants at advanced bases serve a varied load of lighting, heating, and power equipment, most of which demand power day and night. The annual load factor (the ratio of average power to peak power) of a well-operated active base should be 50 percent or more with a power factor (explained later in the chapter) of 80 percent or higher. If the load is more than a few hundred feet from the power source, a high voltage distribution system is required.

If several generators are to serve primary distribution systems, they should generate the same voltage to avoid need for voltage transformation. The number of phases required by the load may differ from that of the generator. As loads can usually be divided and balanced between phases, most generators of appreciable size are wound for three-phase operation.

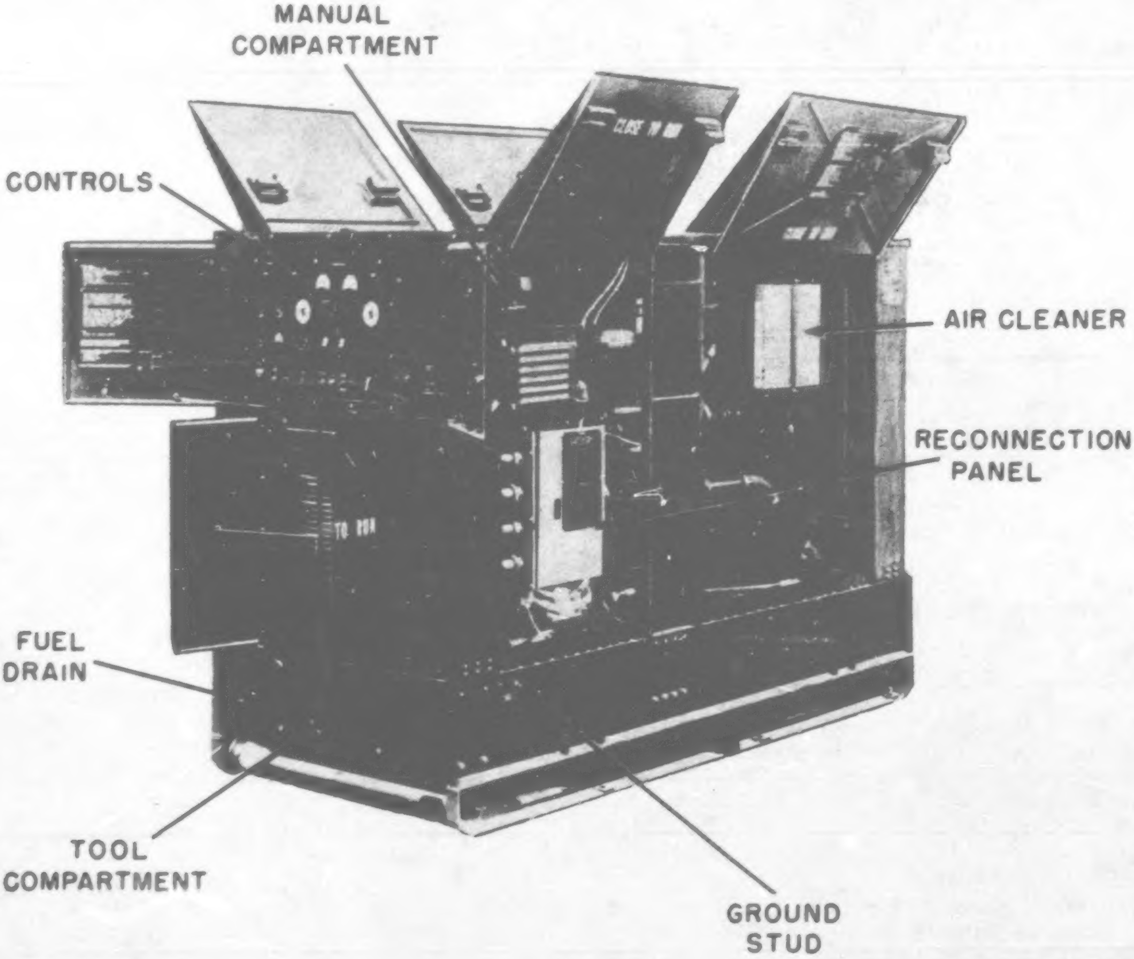


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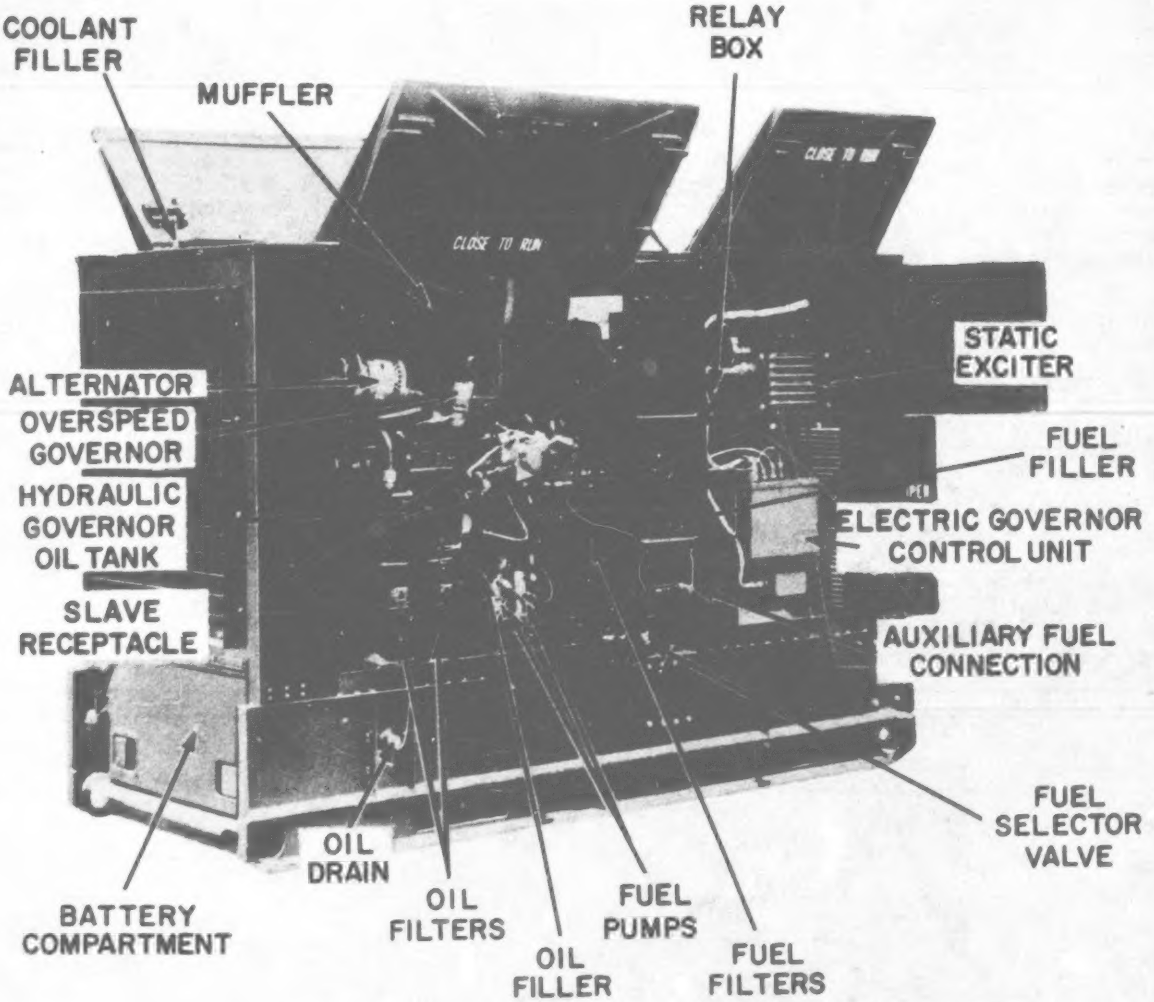
Figure 9-3.—Representative 120/208-volt, three-phase, 4-wire, 60-hertz, portable generator set.


COOLANT FILLER
RELAY BOX
MUFFLER
CLOSE TO RUN
CLOSE TO RUN
STATIC EXCITER
ALTERNATOR
OVERSPEED GOVERNOR
FUEL FILLER
HYDRAULIC GOVERNOR OIL TANK
ELECTRIC GOVERNOR CONTROL UNIT
SLAVE RECEPTACLE
AUXILIARY FUEL CONNECTION
FUEL SELECTOR VALVE
OIL DRAIN
BATTERY COMPARTMENT
OIL FILTERS
FUEL PUMPS
OIL FILLER
FUEL FILTERS

26.244

Figure 9-4.—Generator set, left front, three quarter view.

CONTROL PANELS

A generator must be set up immediately when an advanced base is first occupied, to provide power for temporary lighting, communications, and other services as needed. If the base is to be a permanent one, a central power station must be established for control and distribution of electric power to all spaces and services which are to be located at the base.

Every generator set at an advanced base must have a control panel which may or may not be a built-in part of the unit. The size of the panel and the number and type of controls mounted thereon will depend on the size of the generator unit and the type of equipment for which the station must supply power.

For an initial, temporary unit the panel or control board contains all the necessary meters, switches, and other devices. For a permanent central power station with two main generators, the control panel is a combination of two boards, one for each main generator unit. This assembly is known as "switchgear."

Figure 9-5 shows the control panel for a portable single-generator unit. Figure 9-6 shows the control board of a single generator in a central power station. Figure 9-7 shows the switchgear unit for a central power station containing two diesel-electric plants.

The functions of the controls identified in figure 9-5 are given below.

The STARTER SWITCH controls the starting motor. Pushing the starter switch completes the circuit between the battery and the starting motor.

The THROTTLE normally controls the amount of fuel fed into the cylinders of the engine and therefore controls the speed of the engine. Most of the advanced base generating units are equipped with a GOVERNOR. The governor is an automatic throttle that maintains a constant engine speed by counteracting changes in load. Thus, the frequency output of the generator is kept constant.

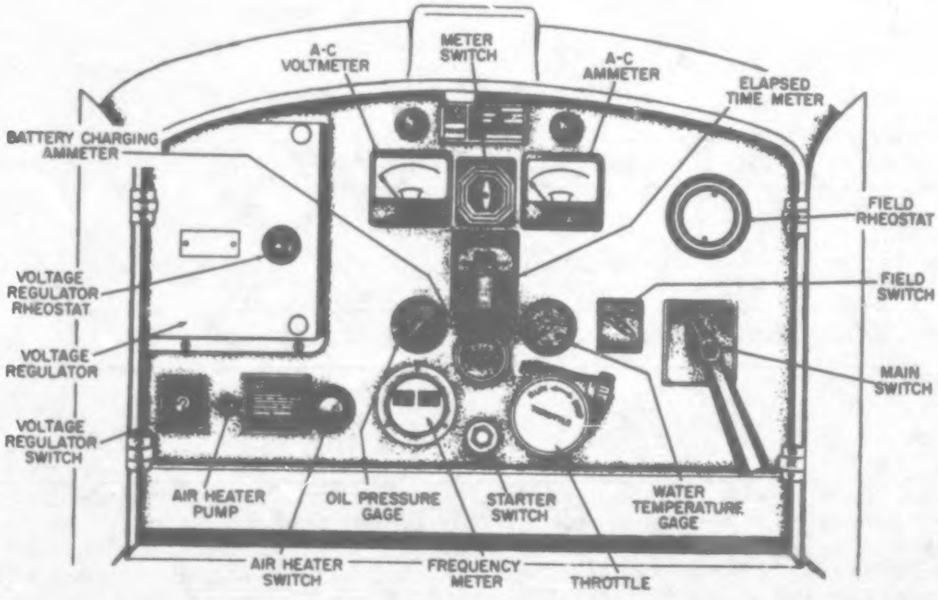
The AIR-HEATER SWITCH controls the current to an ignition system in the air-heater unit installed in the engine. The air-heater unit preheats the ingoing charge of air to the cylinders. This unit is used only for cold-weather starting. The air-heater switch is turned off after the engine has started. It is common practice to preheat the large diesel engines for cold-weather starting. In one preheating method, an AIR-HEATER PUMP is used in conjunction with the air-heater switch. Operating this pump causes oil to flow under pressure from the air-heater unit spray nozzle. The ignition system in the air-heater unit ignites the oil spray. The heat from this miniature oil burner warms the ingoing charge of air.

The ELAPSED-TIME METER indicates the number of hours the engine is in operation. You will record the reading of the elapsed-time meter in the log. It is used to determine when the engine is ready for maintenance or lubrication.

The OIL-PRESSURE GAGE indicates the engine oil pressure. A quick look at this gage tells you the condition of your lubricating system. The normal operating pressure averages about 30 pounds per square inch.

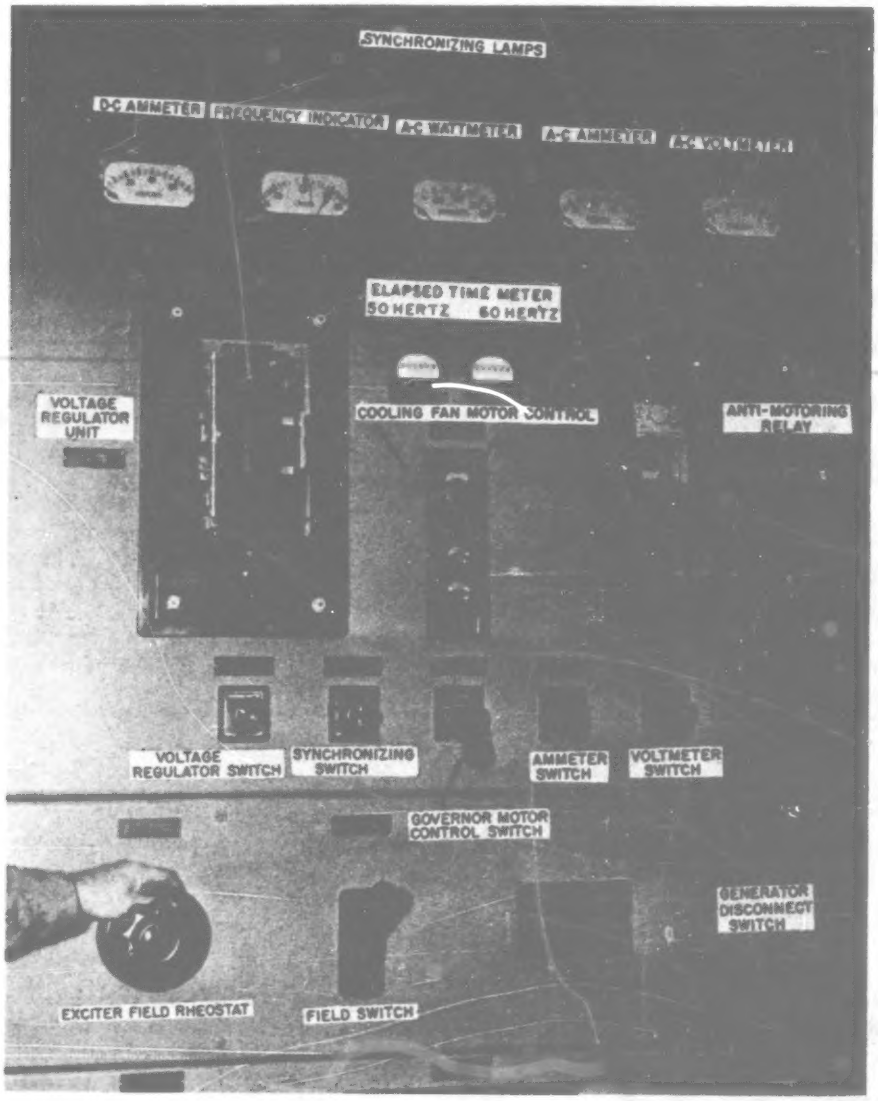
The WATER-TEMPERATURE GAGE indicates the temperature of the cooling water in the engine. The water temperature should read 160-185°F under normal operation of nonpressurized systems.

The BATTERY-CHARGING AMMETER indicates the amount of current sent over to the


A-C VOLTMETER
METER SWITCH
A-C AMMETER
ELAPSED TIME METER
BATTERY CHARGING AMMETER
FIELD RHEOSTAT
VOLTAGE REGULATOR RHEOSTAT
FIELD SWITCH
VOLTAGE REGULATOR
MAIN SWITCH
VOLTAGE REGULATOR SWITCH
AIR HEATER PUMP
OIL PRESSURE GAGE
STARTER SWITCH
WATER TEMPERATURE GAGE
AIR HEATER SWITCH
FREQUENCY METER
THROTTLE

73.63

Figure 9-5.—Control panel for single diesel-driven generator unit.


SYNCHRONIZING LAMPS
D-C AMMETER
FREQUENCY INDICATOR
A-C WATTMETER
A-C AMMETER
A-C VOLTMETER
ELAPSED TIME METER
50 HERTZ
60 HERTZ
VOLTAGE REGULATOR UNIT
COOLING FAN MOTOR CONTROL
ANTI-MOTORING RELAY
VOLTAGE REGULATOR SWITCH
SYNCHRONIZING SWITCH
AMMETER SWITCH
VOLTMETER SWITCH
GOVERNOR MOTOR CONTROL SWITCH
GENERATOR DISCONNECT SWITCH
EXCITER FIELD RHEOSTAT
FIELD SWITCH

73.64

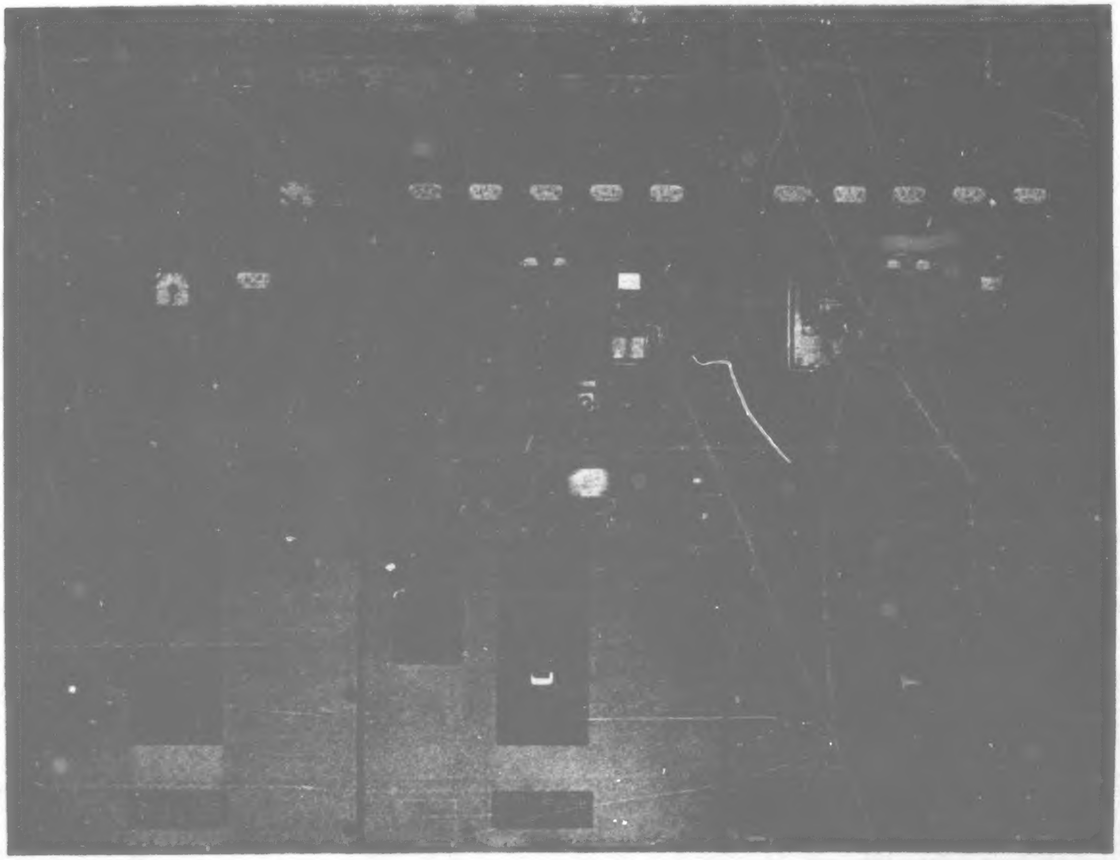
Figure 9-6.— Control board of a single generator in a central power plant.

battery from the charging generator. It also indicates the amount of current being delivered by the battery on discharge.

The FIELD SWITCH controls the output of the exciter. In the OFF position, the switch disconnects the exciter field from the exciter armature. In the ON position, the exciter field is connected to the exciter armature. Since the exciter supplies current to the alternator-field coils, the field switch also controls the alternator output. Before the engine is stopped, the field switch is thrown to the OFF position. This action disconnects the exciter field and at the same time shunts a FIELD-DISCHARGE RESISTOR across the exciter-field coils. The field-discharge resistor absorbs any high voltages which might result from the quick opening of the field circuit.

The FIELD RHEOSTAT is a manually controlled variable resistor that is placed in series with the exciter field. It controls the voltage output of the exciter. The value of the exciter voltage determines the amount of exciter current flowing in the alternator field coils. The amount of exciter current, in turn, controls the voltage output of the alternator. Thus, when you adjust the field rheostat, the result is seen as an increase or decrease of the voltage output of your generator unit.

The VOLTAGE REGULATOR also serves to control the voltage. It makes your generator watch an easy job. Without the voltage regulator it would be necessary for you to change the field-rheostat setting each time the output voltage of your generator unit varied from its normal value. The voltage regulator does this for you automatically. Like the field rheostat, the voltage regulator is a variable resistance in series with the exciter field. The resistance is varied automatically by a control unit. The control unit takes changes in generator voltage and converts them to changes in mechanical motion. The changes in mechanical motion will increase or decrease the voltage regulator resistance. In this manner the output of your generator is kept at a constant value.



73.65

Figure 9-7.—Switchgear unit for central power station.

The VOLTAGE-REGULATOR SWITCH in the ON position puts the voltage-regulator unit to work. With the switch in the OFF position you must use the field rheostat to adjust the voltage output of the generator unit.

The VOLTAGE-REGULATOR RHEOSTAT is a small variable resistor mounted on the voltage-regulator unit. It is in operation only when the voltage regulator is in the circuit. The setting of the voltage-regulator rheostat determines the value of voltage kept constant by the voltage regulator.

The A-C VOLTMETER indicates the voltage output of your generator unit. When you adjust your field rheostat or voltage-regulator rheostat you will be watching the a-c voltmeter. It will tell you when you have reached the generator's rated voltage output.

The A-C AMMETER indicates the current output of your generator unit. Any overload or unbalancing of a line can be spotted with this instrument.

The METER SWITCH is necessary because this particular unit is a three-phase generator. Each position of the switch puts the a-c voltmeter and the a-c ammeter in a different leg of the three-phase line. Thus you are able to read the voltage across any two legs and the current in any one leg. The OFF position of the switch disconnects the ammeter and voltmeter completely.

The FREQUENCY METER measures the frequency (hertz) of the voltage generated by the alternator.

The SYNCHRONIZING LAMPS are used when the generator unit is being paralleled with another generator.

The MAIN SWITCH opens or closes the circuit between the generator and the load. Remember that it doesn't shut the engine off. In most cases the main switch will have a built-in CIRCUIT-BREAKER. This device will automatically open the main switch whenever a continuous overload current appears on the line.

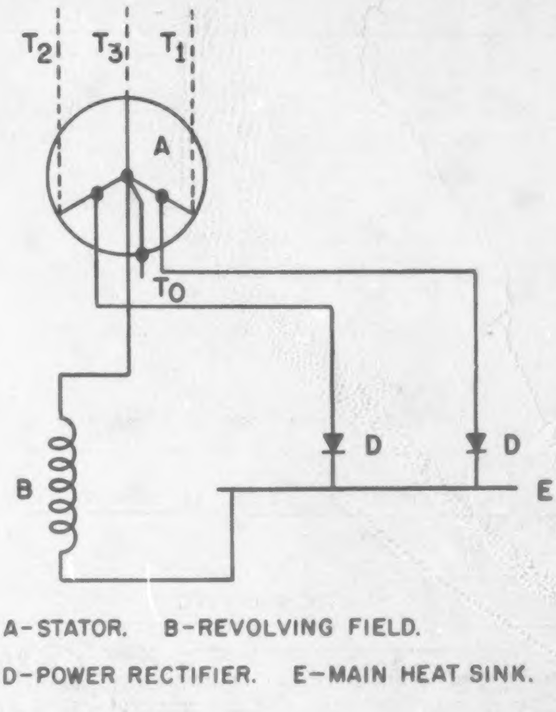
All of these meters, switches, and controls mounted on the face of a panel board or switchgear unit either control or are controlled by other equipment located behind the board. For example: the output cables from the generator are brought to the back of the switchgear and connected to the line terminals of the main switch. The load terminals of the main switch are connected to the bus bars. These bus bars are bar conductors which serve as collection and distribution points—that is, they receive the power generated by the system, and distribute the same to the distribution circuits leading to the various points of consumption.

SWITCHBOARD CONTROLS

The switchboard instruments should include an indicating wattmeter to avoid the necessity for making numerous ammeter and voltmeter readings to compute power output. If records must be kept on generator efficiency, a watt-hour meter is also needed.

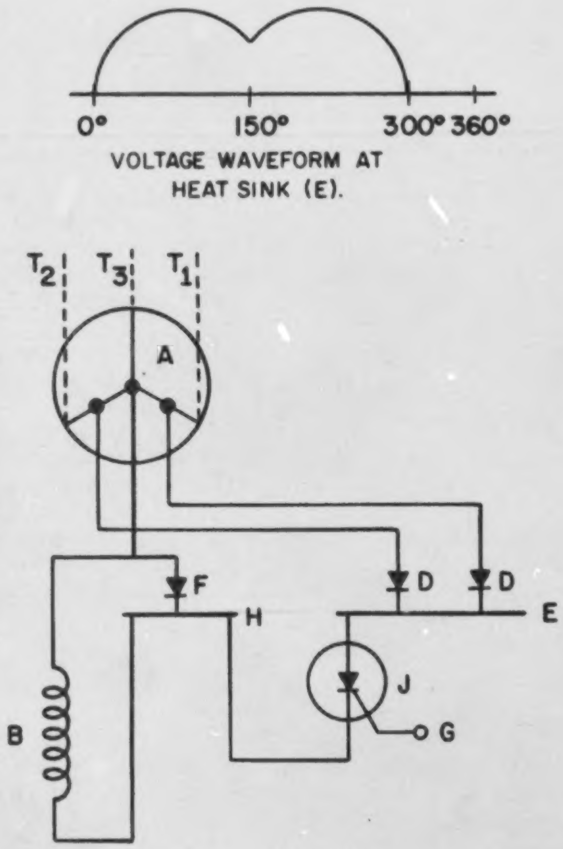
Remember that the voltmeter measures the voltage of the bus, not that of any one generator contributing to the bus voltage. Ammeters, however, should be connected in series with at least one lead of the output of each generator. If only a single ammeter is available for measuring three-phase current, it must be switched to the different phases.

A group of lamps connected across the bus, and with a center point grounded, provides a


T_2
T_3
T_1
A
T_O
B
D
D
E
A-STATOR. B-REVOLVING FIELD.
D-POWER RECTIFIER. E-MAIN HEAT SINK.

73.337

Figure 9-8.—Field excitor.



A-STATOR. B-REVOLVING FIELD.
D-POWER RECTIFIER. E-MAIN HEAT SINK.
F-FIELD RECTIFIER. H-AUXILIARY HEAT SINK.
J-CONTROLLED RECTIFIER.

73.338

Figure 9-9.—Field rectifier.

practical means for detecting any accidental ground.

STATIC CONTROLS

In today's field generating plant you will be operating and maintaining Statically Regulated Controlled Rectifier (SRCR) generators. They vary in size and manufacturer, and require less maintenance, are more compact and lightweight, and give better voltage regulation than the older types which required movable mechanical parts and electrical contact points.

OPERATION THEORY OF SRCR GENERATORS

Residual magnetism in the field poles (fig. 9-8) will allow the generator to produce approximately 3 to 5% of rated voltage. Two of the three phases are tapped to provide a-c for the field excitation. Two power rectifiers (D) change this to d-c and are mounted on the main heat sink (E). The direct current from the power rectifiers is fed through brushes and slip rings to the field windings (B) and adds to the residual magnetism to increase the output voltage.

Since the generator voltage would increase without control in the circuit as shown, a method of limiting and controlling is required. The field rectifier (F) in figure 9-9 mounted on an auxiliary heat sink (H) maintains field current flow when the excitation voltage drops to zero

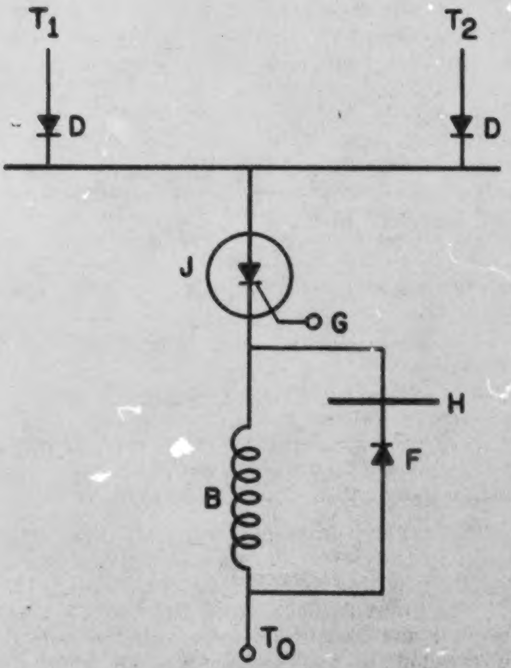


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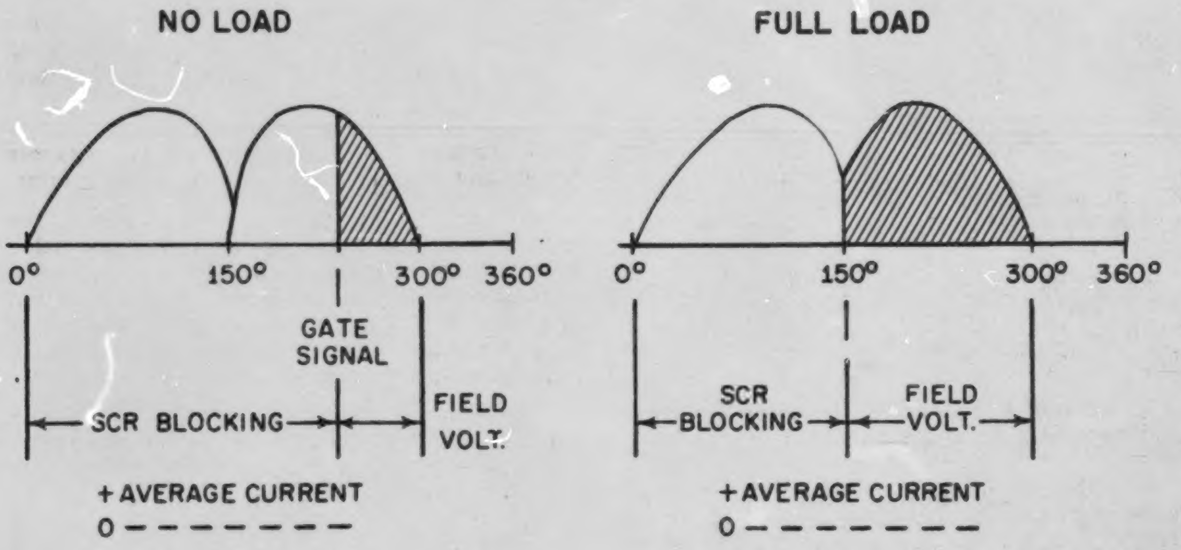
Figure 9-10.—Controlled rectifier.



73.340

Figure 9-11.—Field current.

for 60° of field rotation. This current flow is due to the collapsing magnetic field which represents stored electrical energy.

The silicon controlled rectifier (J) in the field circuit (figs. 9-9 and 9-10) provides the means of controlling field current, hence output voltage. This rectifier will not conduct until a positive voltage is applied to the gate terminal (G). It has to be turned on every cycle since the 60° time that the voltage is zero turns it off at the end of every cycle. The pulses of current form an average value of current which maintains the generator at rated voltage.

The field current is turned on during each cycle (fig. 9-11). At no load the silicon controlled rectifier (SCR) allows little current to reach the field. At full load the SCR allows a larger current to reach the field.

WARNING

When a statically regulated controlled rectifier generator is running, do not touch the aluminum heat sink assembly on the back of the chassis as it is electrically charged. The rectifier may be damaged if metal contact is made between the heat sink and the generator frame.

VOLTAGE CONTROL CIRCUIT

The voltage buildup relay (L) in figure 9-12 applies a positive voltage to the gate of the rectifier (J) and turns it on when the generator is being started. The closed contacts apply the positive heat sink (E) voltage to the gate of the SCR.

The buildup resistor (BR) is a piece of nichrome wire on the relay socket base.

Blocking diode (BD) protects the rectifier (J) from failure in case the power rectifiers (D) short.

The relay contacts open when the generator reaches 60% of the rated voltage. The regulator assembly (X) controls the rectifier (J) after the voltage builds up.

Regulator Assembly (X) turns on the rectifier (J) every cycle (60 times per second) to allow field current to flow. The amount the regulator assembly allows current to flow depends on the generator load. The regulator assembly changes the amount of field current flowing by turning on the rectifier (J) sooner or later in the cycle.

The regulator assembly contains a voltage level sensing circuit and a SCR triggering circuit. The triggering circuit does the actual triggering of the SCR but the voltage level sensing circuit tells the triggering circuit when to turn the SCR on.

The voltage level sensing circuit in figure 9-13 which feeds a signal into the regulator assembly (X), contains the following parts.

1. A voltage level potentiometer (N) provides a means of adjusting the voltage level. The voltage level is changed by adjusting the amount of voltage applied to the regulator assembly through the isolation transformer (P).

2. Sensing reactor (M) makes the regulator circuit independent of generator frequency. The regulator responds now at the same rate as the engine governor.

3. Isolation transformer (P) isolates the regulator assembly from the rest of the generator.

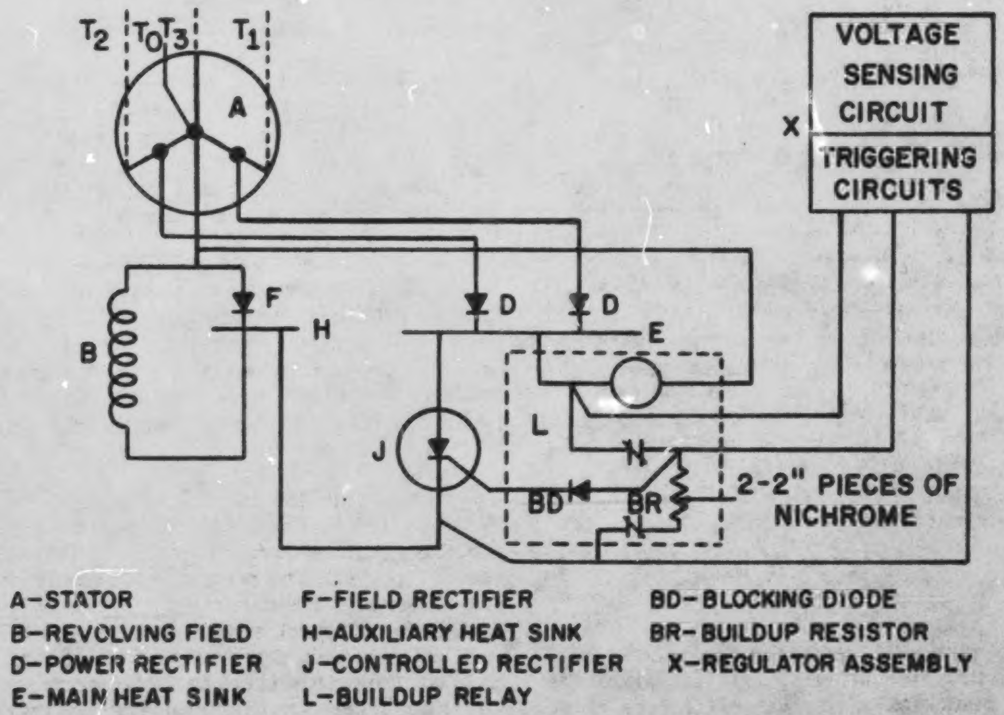
4. Filter choke (Q) increases the stability of the regulator assembly by smoothing out the voltage that the voltage sensing circuit sends to the triggering circuit.

5. Voltage droop transformer (T) provides the additional control circuit voltage required to produce the desired voltage droop when operating in parallel.

6. Voltage droop potentiometer (U) controls the amount of voltage droop added to the regulator.

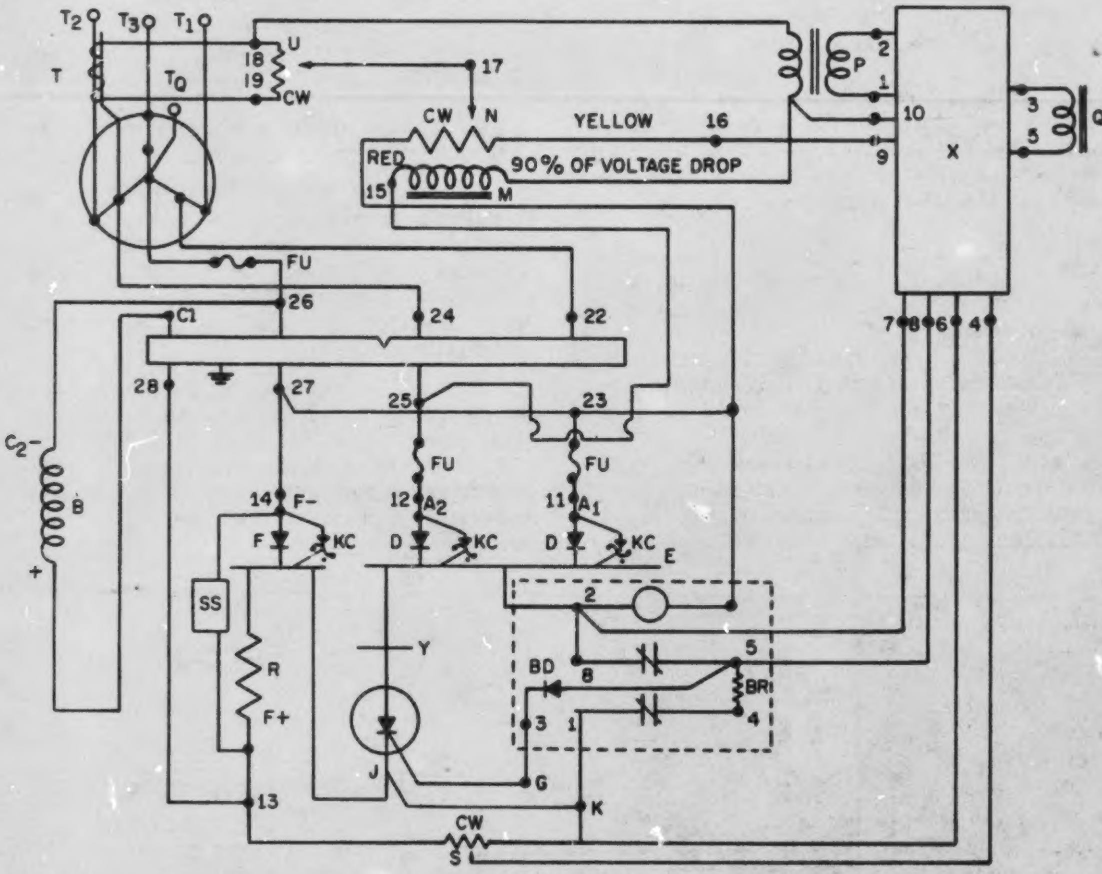
By sensing the generator field current, the regulator gain control (S) holds the generator voltage constant as the engine speed droops from no load to full load. The generator field current produces a voltage droop across the regulator gain resistor (R) and the gain control is in parallel with the resistor.

The noise suppression assembly (V) eliminates the radio static produced by the generator. The noise suppressor has coils in series with the lines and capacitors connected to ground. An additional surge suppressor is connected across the field rectifier (F) to protect it from short high voltage pulses.


T2
T0
T3
T1
A
VOLTAGE SENSING CIRCUIT
X
TRIGGERING CIRCUITS
B
F
H
D
D
E
L
J
BD
BR
2-2" PIECES OF NICHROME
A-STATOR
B-REVOLVING FIELD
D-POWER RECTIFIER
E-MAIN HEAT SINK
F-FIELD RECTIFIER
H-AUXILIARY HEAT SINK
J-CONTROLLED RECTIFIER
L-BUILDUP RELAY
BD-BLOCKING DIODE
BR-BUILDUP RESISTOR
X-REGULATOR ASSEMBLY

73.341

Figure 9-12.—Voltage buildup relay.


T2
T3
T1
T
TQ
U
18
19
CW
17
CW
N
YELLOW
16
RED
90% OF VOLTAGE DROP
15
M
P
2
1
10
9
X
3
5
Q
FU
26
24
22
C1
7
8
6
4
C2-
B
+
28
27
25
23
FU
FU
14
F-
12
A2
11
A1
F
KC
D
KC
D
KC
E
SS
2
5
R
Y
BD
8
BR
F+
3
1
4
J
G
13
K
CW
S

A-STATOR
B-ROTATING FIELD
D-POWER RECTIFIER
E-MAIN HEAT SINK
F-FIELD RECTIFIER
H-AUXILIARY HEAT SINK
J-CONTROLLED RECTIFIER

L-BUILD-UP RELAY
M-SENSING REACTOR
N-VOLTAGE LEVEL POTENTIOMETER
P-ISOLATION TRANSFORMER
R-REGULATOR GAIN RESISTOR
S-REGULATOR GAIN POTENTIOMETER
T-VOLTAGE DROOP TRANSFORMER

U-VOLTAGE DROOP TRANSFORMER
V-NOISE SUPPRESSION ASSEMBLY
X-REGULATOR ASSEMBLY
Y-CONTROLLED RECTIFIER HEAT SINK
SS-SURGE SUPPRESSOR
FU-FUSE
KC-KLIP-CEL VOLTAGE SURGE SUPPRESSOR

73.342

Figure 9-13.—SRCR control.

The fuses (FU) are extremely fast blowing to protect the circuit from high current.

The klip-cels (KC) reduce voltage pulses across the rectifiers. The voltage pulses could occur when large loads are disconnected from the generator.

Instrument Transformers

The voltage and currents delivered by a generating system to the bus bars are too high for safe operation of most of the switchboard apparatus, particularly the switchboard instruments. Instrument transformers, therefore, are mounted on the back of the switchboard and connected to the bus bars. Their purpose is to step down the voltages and currents fed to instruments, relays, voltage regulators, and the like. By the use of transformers, switchboard apparatus can be insulated from the high-voltage circuit, yet receive enough power to indicate accurately the voltage, current, and power in the circuit.

Transformers used to reduce high current values to the small values required to operate ammeters, or to operate current coils in other instruments, are called current transformers. Transformers which reduce high voltages to smaller voltages required to operate voltmeters or the potential coils of other instruments are known as "voltage" or "potential" transformers.

The primary winding of a current transformer may consist of a few turns around a laminated iron core, or it may, in some cases, consist of the bus bar or cable carrying the line current. The primary winding is always connected in series with the line.

The secondary winding consists of several turns of relatively small wire wound around a laminated core. It is the secondary, of course, that is connected to the ammeter or other instrument or switchboard device. The current rating of the secondary on practically any current transformer is 5 amperes, regardless of the current rating of the primary.

The secondary of a current transformer should never be open-circuited while the primary is energized. An open-circuited current transformer might develop several thousand volts across the secondary, where there would be only a few millivolts (a millivolt is 0.001 volt) if the secondary circuit were closed. This high voltage might well cause severe, even fatal, shock to the operator. It would in any case break down insulation and destroy the transformer. Hence the invariable rule: NEVER OPEN THE SECONDARY OF A CURRENT TRANSFORMER WHEN IT IS CONNECTED IN THE CIRCUIT.

Potential (voltage) transformers have a low current rating. The low side of the transformer is usually wound for 110 volts, and the ratio of turns on one side to turns on the other is determined by the rating of the high-voltage side. The primary is connected across the voltage source to be measured, and the secondary is connected to the meter or other instrument or device. The current through the potential transformer depends on the load of the meter or other device. This load is always constant.

The secondary should always be grounded at one terminal, to eliminate static from the measuring instrument, and also to protect personnel. Again there is an important safety precaution: NEVER SHORT-CIRCUIT THE SECONDARY OF A POTENTIAL TRANSFORMER.

Synchroscopes

The SYNCHROSCOPE is a phase relation meter connected so as to measure the phase

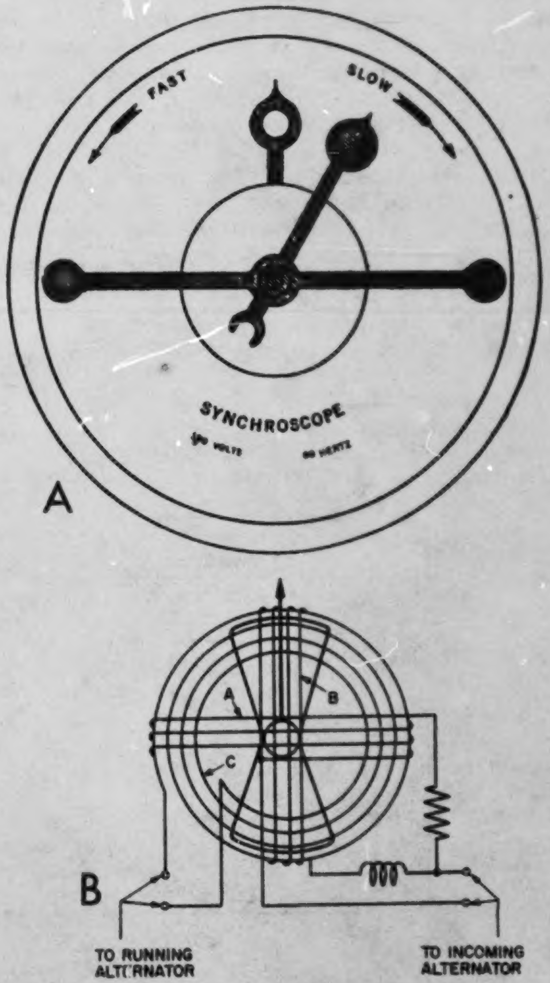


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Figure 9-14.—Dial face and wiring diagram of a synchroscope.

relation between generator voltage and bus bar voltage when an additional generator is being put on the line.

With a synchroscope you determine (1) whether the frequencies of the alternators are the same or different, (2) whether frequency is constant for an appreciable time, and (3) whether or not the voltages of both generators are in phase—that is, whether they reach maximum value at the same time.

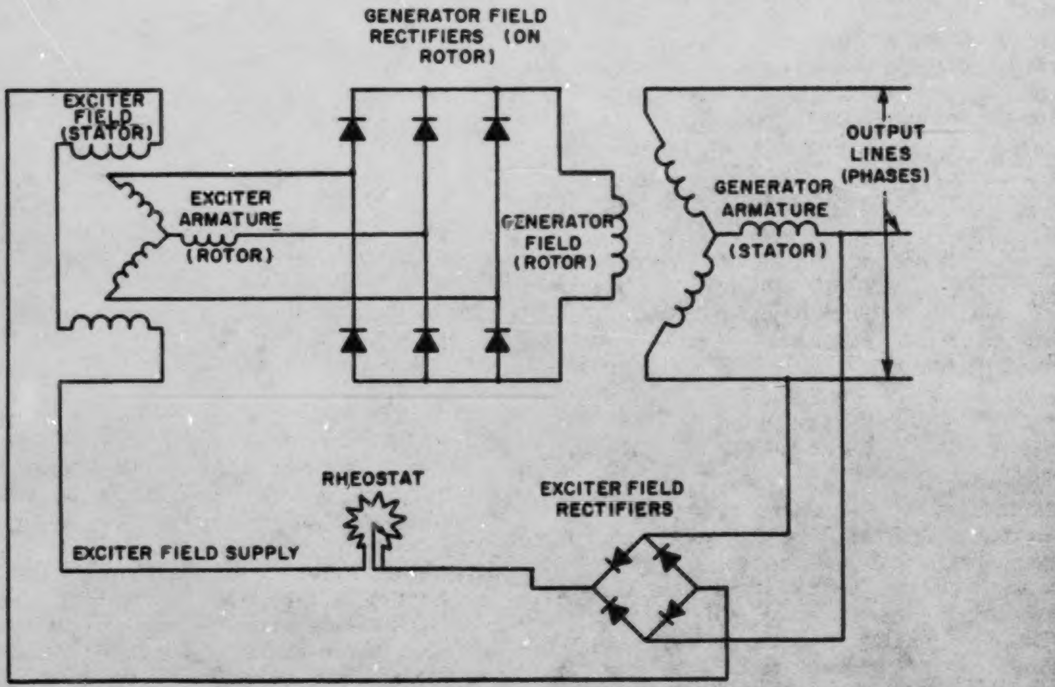
Figure 9-14A shows the dial of a synchroscope, figure 9-14B a wiring diagram of the instrument. Coils A and B are connected to the incoming generator through a potential transformer. Coil C is connected to the bus line. One pointer holds a fixed position at the top of the dial as shown in figure 9-14. The moving element is attached to the second, movable pointer. If the frequencies are the same, this pointer takes a fixed position. With any slight variation in frequency, however, it will begin to travel—toward SLOW if the incoming generator is slow, toward FAST if it is fast. The amount of difference in frequency is indicated by the speed of travel.

BRUSHLESS GENERATORS

Figure 9-15 shows an elementary circuit diagram for a brushless generator system. Elimination of brushes, slip rings, and commutators is accomplished by placing a rectifier assembly, generator field and exciter armature on the rotor.

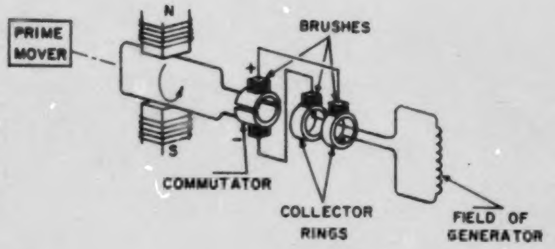
In the brush type of a-c generator (fig. 9-16), the field current is transferred from the rotating part of the machine to the generator field by the use of commutator, brushes and collector rings. Much time is spent on the maintenance of these components.

Brushless type rotating exciters (fig. 9-17) eliminate the necessity for commutator, collector rings and brushes by applying the a-c output of the exciter armature to silicon rectifiers connected in a bridge. The d-c rectified output is then applied directly to the field. Since


GENERATOR FIELD RECTIFIERS (ON ROTOR)
EXCITER FIELD (STATOR)
EXCITER ARMATURE (ROTOR)
GENERATOR FIELD (ROTOR)
GENERATOR ARMATURE (STATOR)
OUTPUT LINES (PHASES)
RHEOSTAT
EXCITER FIELD RECTIFIERS
EXCITER FIELD SUPPLY

73.307

Figure 9-15.—Brush type rotating exciter.



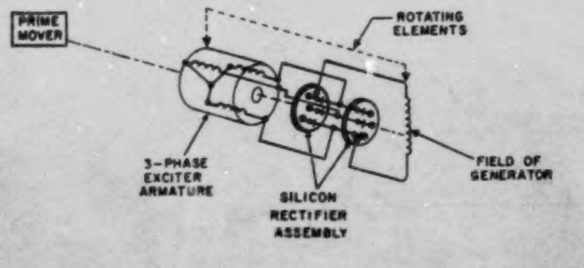
73.308
Figure 9-16.—Basic brushless generator.

all these components are mounted on the rotor, no need exists for brushes, commutator or slip rings, making the entire unit compact, simple, and free of sparking. Maintenance is thus reduced.

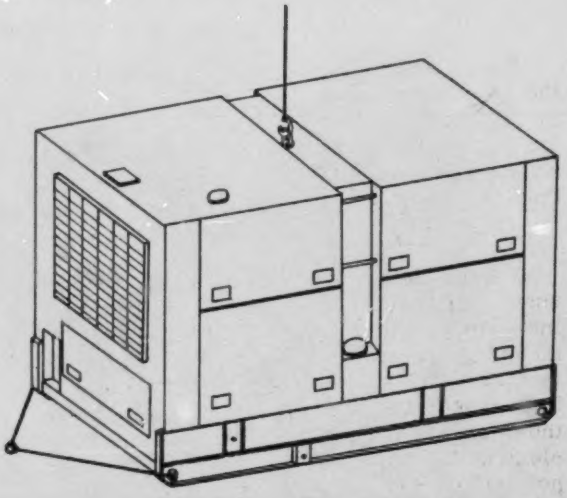
GENERATOR INSTALLATION

In setting up the generator try to place the equipment near points of large demand, to reduce the size of wire required, to hold the line losses to a minimum, and to afford adequate voltage control at the remote ends of the lines. Generators must not be closer than 25 feet to a load, because of noise, fire hazard, and air circulation.

Moving the generator may be accomplished by lifting or pulling (fig. 9-18). The generator set comes equipped with a lifting sling usually stowed in the skid on the side of the unit opposite the operator's control panel.



73.309
Figure 9-17.—Brushless type rotating exciter.



26.248
Figure 9-18.—Towing and lifting slings.

POWER AND VOLTAGE REQUIREMENTS

The power and voltage requirements of the load will normally determine the size of the generator to be used. For example, electrical equipment rated at 120 volts, single phase with a combined power load of less than 1500 watts can be adequately handled by a gasoline- or diesel-driven power plant with a 120-volt, 2-wire output rated at 1.5 kw. If the power demand of the equipment is greater than 1.5 kw, but does not exceed 4.5 kw, a generator rated at 5 kw, 120 volts, with a 2-wire output can be used.

The selection of voltage is affected by the size, character, and distribution of the load; length, capacity, and type of transmission and distribution circuits; and size, location, and connection of generators. Practically all general purpose lighting in the United States and at United States overseas bases is 120 volts. The lighting voltage may be obtained from a 3-wire, 120/240-volt, single-phase circuit or a 120/208-volt, three-phase, 4-wire circuit. Some small motors can be supplied by direct current or single-phase alternating current at nominally 120 volts. Large three-phase, a-c motors, above 5 horsepower, will generally operate satisfactorily at any voltage between 200 and 240.

Demand Factor

Electrical loads are generally measured in terms of amperes, kilowatts, or kilovoltamperes. In general, electrical loads are seldom constant for any appreciable time, but fluctuate constantly.

The connected load is the sum of the rated capacities of all electrical appliances, lamps, motors, and so on, connected to the wiring of the system. The maximum demand load is the greatest value of all connected loads that are in operation over a specified period of time.

The ratio between the actual maximum demand and the connected load is called the demand factor. If a group of loads were all connected to the supply source and drew their rated loads at the same time the demand factor would be 1.00. There are two main reasons why the demand factor is usually less than 1.00. First, all load devices are seldom in use at the same time, and even if they are, they will seldom reach maximum demand at the same time. Secondly, some load devices are usually slightly larger than the minimum size needed and normally draw less than their rated load.

Power Factor

Power factor (PF) is a ratio or percentage relationship between watts of a load and the product of volts and amperes necessary to supply that load. Watts (W), the measure of actual power, is the product of volt and ampere values at any one instant. Volt-amperes, the measure of volts (E) and current (I) on the line, is the product of the units, regardless of their time displacement. These products are also referred to as true power (watts) and apparent power (volt-amperes).

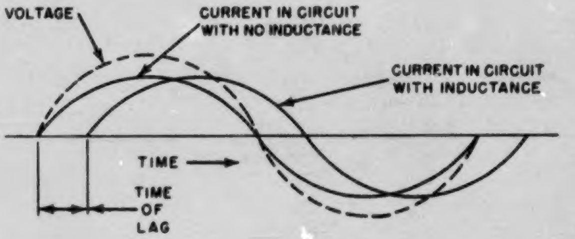
$$\text{Power factor} = \frac{\text{true power}}{\text{apparent power}} = \frac{\text{watts}}{\text{volt-amperes}} = \frac{W}{\Sigma \times I}$$

For single-phase circuits

$$W = E \times I \times PF \text{ or } I = \frac{W}{E \times PF}$$

For 3-phase circuits, the constant 1.73 must be introduced into the equation. Therefore,

$$I = \frac{W}{E \times PF \times 1.73}$$


VOLTAGE
CURRENT IN CIRCUIT WITH NO INDUCTANCE
CURRENT IN CIRCUIT WITH INDUCTANCE
TIME →
TIME OF LAG

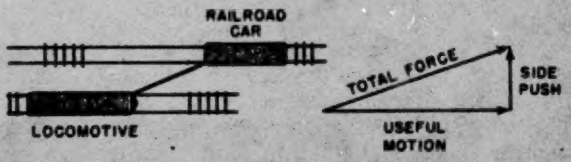
26.245

Figure 9-19.—Inductance makes current lag behind voltage.

Inductance in a circuit lowers the power factor by causing the current to lag behind the voltage, as illustrated in figure 9-19. If the voltage and current curves start together, reach maximum at the same time, and pass through 0 together, the circuit has a power factor of 1 or 100%.

A power factor of 1 or 100% means that no time lag exists and that watts equals volt-amperes. A 50 percent power factor means that watts are only 1/2 the volt-ampere product and that twice as much current is required to produce a given amount of power, compared with 100 percent power factor.

The power factor is illustrated in figure 9-20 which shows a railroad car being pushed by a locomotive. If the locomotive were on the same track pushing directly from behind it, all the force would be useful work. However, if the locomotive is on a parallel track as shown, the amount of force may be the same, but the actual push on the car is not the same because some force tends to push the car sideways off the track. The power output from the locomotive is divided between actual work and the lost force. In other words, real power is less than apparent power. The situation is similar to that of an electrical circuit where time lag exists and the real or true power is less than the apparent power.



26.246

Figure 9-20.—Illustration of power factor.

Power loads from drive motors and constant-current regulators reduce the power factor most because they require large amounts of reactive power in their operation. Reactive power is apparent power used by inductive loads, that is, inductance in a circuit. Other appliances, such as welders, may also require reactive power. Loads, such as electric heaters and heating appliances, that are due to resistance only do not affect the reactive power.

SHELTERING GENERATORS

Although advanced base portable generators are designed to be operated outdoors, prolonged exposure to wind, rain, and other adverse conditions will definitely shorten their life. If the generators are to remain on the site for any extended period of time, they should be mounted on solid concrete foundations and should be installed under some type of shelter.

There are no predrawn plans for shelters for a small advanced base generating station. The shelter will be an on-the-spot affair, the construction of which is determined by the equipment and material on hand plus your ingenuity, common sense, and your ability to cooperate with men in other ratings. Before a Builder can get started on the shelter, you will have to furnish information, such as the number of generators to be sheltered; the dimensions of the generators; the method of running the generator load cables from the generator to the bus bar and from the bus bar to the feeder system outside the building; and the arrangement of the exhaust system.

Large generator units may have, connected or attached to them, engine equipment that requires extra space and working area. Included in this equipment are: air-intake filters, silencers for air intake and exhaust, fuel and lubricating oil pumps, tanks, filters and strainers, starting gear, isochronous regulating governors with overspeed trips, safety alarm and shutdown devices, gages and thermometers, turning gear, and platforms, stairs, and railings.

An even larger and more complete power plant may require separate equipment, such as a motor-driven starting air compressor and air storage tanks; motor-driven pumps for jacket water and lubricating oil cooling, or heat exchangers with raw cooling water pumps and lubricating oil coolers; and tanks, including day-fuel storage.

Installation specifications are available in the manufacturer's instruction manual that accompanies each unit. Be sure to use them. Consulting your Builder about these specifications may help cut installation costs and solve piping problems.

The following hints and suggestions will also be helpful.

1. Consider ventilation when installing the units inside a building. Every internal combustion engine is a HEAT engine. Although heat does the work, excess amounts of it must be removed if the engine is to function properly. This can be accomplished by setting the engine's radiator grill near an opening in the wall and providing another opening directly opposite the unit. In this manner, cool air can be drawn in and the hot air directed in a straight line outdoors. These openings can be shielded with adjustable louvers to prevent the entrance of rain or snow. In addition, when operating in extremely cold weather, the temperature in the room can be controlled by simply closing a portion of the discharge opening. Additional doors or windows should be provided in the shelter if the plants are installed in localities where the summer temperatures exceed 80°F at any time.

2. Be sure to provide enough working space around each unit for repairs or disassembly and for easy access to the generator control panels.

3. Do not allow carbon monoxide gas to collect in a closed room; this gas is extremely poisonous. Discharge the engine's exhaust to the outdoors by extending the engine's exhaust pipe through the wall or roof of the building. Support the exhaust pipe and make certain that no obstruction or too many right angle bends are used. Also, whenever possible, arrange the exhaust system so that the piping slopes away from the engine. In this way, condensation will not drain back into the cylinders. If the exhaust pipe should have to be installed so that loops or traps are necessary, a drain cock should be placed at the lowest point of the system. All joints must be perfectly tight, and where the exhaust pipe passes through the wall, care must be taken to prevent the discharged gas from returning along the outside of the pipe back into the building. Exhaust piping inside the building must be covered with insulation capable of withstanding a temperature of 1500°F.

ELECTRICAL INSTALLATION

As a CE your prime concern will be with the electrical installation. You will have to insure the generator is in good working order, grounded properly, connected for the proper output voltage, and protected against overloads and shorts when tied to the load.

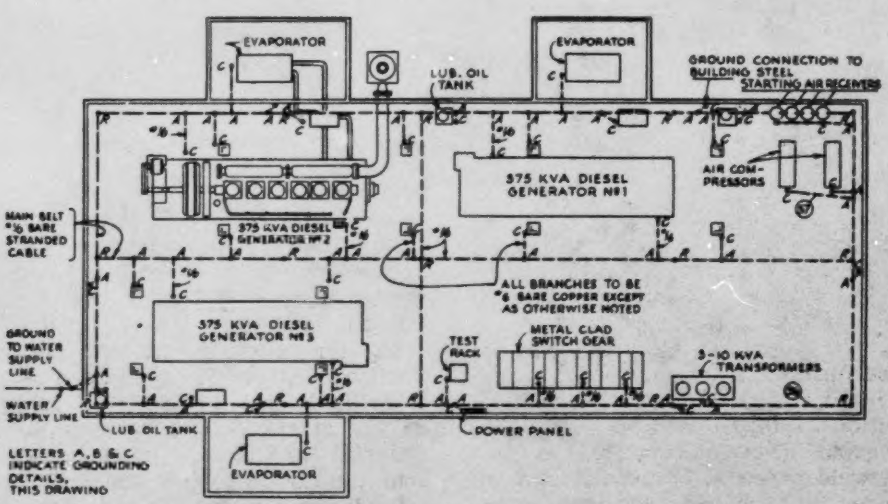
GROUNDING

The metal cabinet in which each power panel is mounted, and the neutral bus in the switchgear unit, must be grounded. However, there are many metal noncurrent-carrying parts of the distribution system that must be grounded as well. It is the custom, therefore, to draw up a plan or system which will ensure grounding of all metal parts, such as the bases and frames of motors and generators, the steel tanks of distribution transformers, switchgear apparatus, and any other metal parts which might permit development of an electrostatic field.

Figure 9-21 shows a representative grounding plan. The dotted lines represent grounding cables. The letter "R" denotes the locations of driven ground rods. The letter "A" indicates points at which branch cables are connected to the equipment. Bare stranded copper cable is used throughout the system, with size 1/0 AWG used for the main ground and for the branch cables.

The preferred ground is a buried metallic water piping system. In the absence of such a piping system, a driven solid metal rod, a driven metal pipe, or a buried metal plate can be the ground. The ground rod must be at least 5/8 inch in diameter, the ground pipe at least 3/4 inch. Both must be driven into the earth to a depth of 8 feet or more. The ground plate must have a minimum surface area of 2 square feet and be buried at a minimum depth of 4 feet. The rod, pipe, plate, or piping system is bolted or clamped to the ground lead (one end of a No. 6 AWG copper wire). The other end of this lead is connected to the ground stud on the generator set.

The usual method is to install the preliminary features of the grounding system during the early stages of base construction. Cables must be laid and ground rods driven before the concrete foundations and decks are poured. When the power plant has been installed, the branch cables are connected at one end to the equipment and at the other end to the main belt of cable encircling and running through the station. This main cable is earth-grounded at frequent intervals throughout its run (see letter "R" points in fig. 9-21).

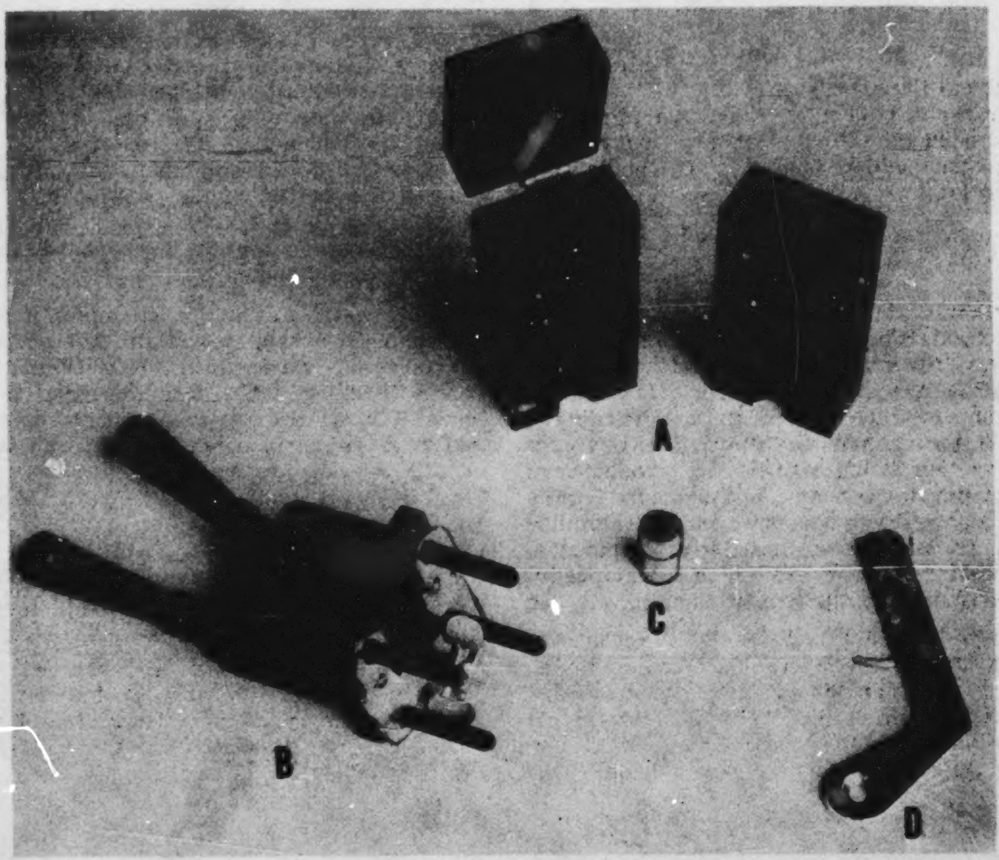

EVAPORATOR
EVAPORATOR
LUB. OIL TANK
GROUND CONNECTION TO BUILDING STEEL
STARTING AIR RECEIVERS
375 KVA DIESEL GENERATOR Nº1
AIR COMPRESSORS
375 KVA DIESEL GENERATOR Nº2
MAIN BELT #1/0 BARE STRANDED CABLE
ALL BRANCHES TO BE #6 BARE COPPER EXCEPT AS OTHERWISE NOTED
375 KVA DIESEL GENERATOR Nº3
METAL CLAD SWITCH GEAR
TEST RACK
3-10 KVA TRANSFORMERS
GROUND TO WATER SUPPLY LINE
WATER SUPPLY LINE
LUB OIL TANK
POWER PANEL
EVAPORATOR
LETTERS A, B & C INDICATE GROUNDING DETAILS, THIS DRAWING
A
R
C
#10

PLAN OF GROUNDING SYSTEM

SCALE 1/8"=1'-0"

73.66

Figure 9-21.—Representative grounding plan for advanced base power plant.



73.67

Figure 9-22.—Equipment and material used for Cadweld process.

One way to connect branch cables to main cables and the main cables to ground rods is by the use of "ground clamps." However, metal clamps tend to corrode, and corrosion causes high resistance (ground resistance must be less than 1 ohm). To overcome this problem, the metal must be cleaned thoroughly and the connection made very tight. Periodic inspections of the connections must be made to ensure that resistance to ground does not develop.

A thermit weld process, called the Cadweld process, is used on Navy installations to eliminate the problem of developing resistance in groundclamp connections. No outside source of power or heat is required for this process. The equipment includes a mold which is clamped over ground rod and cable, or over main and branch cables, at the point of connection. The lower part of this mold has cavities which receive the items to be joined. The upper part has a cavity into which first a metal oxide is poured, and next a starting powder which, upon being ignited, burns at very high temperature. The starting powder is ignited by a spark from a welder's flint lighter. The resulting reaction in the starting powder melts the metal oxide, which flows from the upper recess in the mold into the lower, cools and hardens there, and thus fuses the items to be connected together.

Because the reaction occurs quickly and with high thermal efficiency, the process is ideally suited for joining copper conductors. Normally the weld is completed 10 seconds after the powder is ignited. The short heating process helps protect long conductors against insulation damage due to prolonged exposure to heat.

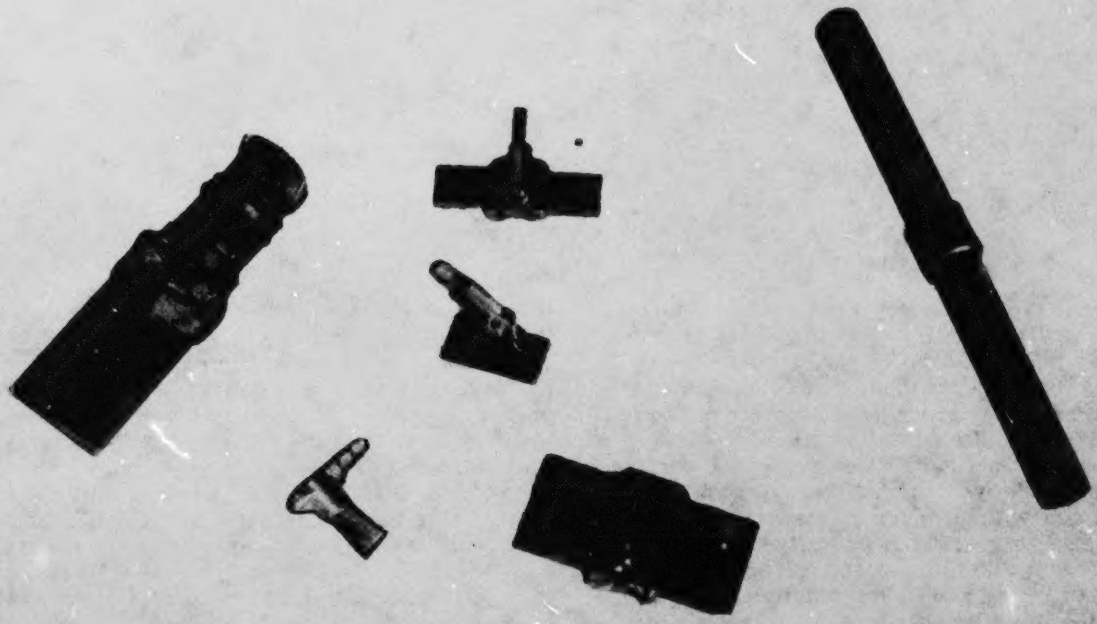
Figure 9-22 shows Cadweld equipment and material used to weld a ground conductor to a ground rod. A is the mold, B is the clamp which holds the mold in position, C is the cartridge containing the powdered metal oxide and the starting powder, and D is a welder's flint lighter. Figure 9-23 shows some welds made by the Cadweld process.

GENERATOR CONNECTIONS

When installing a power plant that has a 220/440-volt, 208/416-volt or other dual-voltage alternator unit, you must connect the armature coil leads properly to produce the voltage required by the equipment. Take a look at figure 9-24. It shows a dual-voltage alternator unit that has been disconnected and removed from a three-phase diesel-driven power plant. The stator or stationary armature coils and core are mounted in the frame of the generator. The a-c voltages generated in the coils are brought through an opening in the pedestal of the frame by means of 10 coil leads. Each coil lead is identified by a number stamped on a metal band.

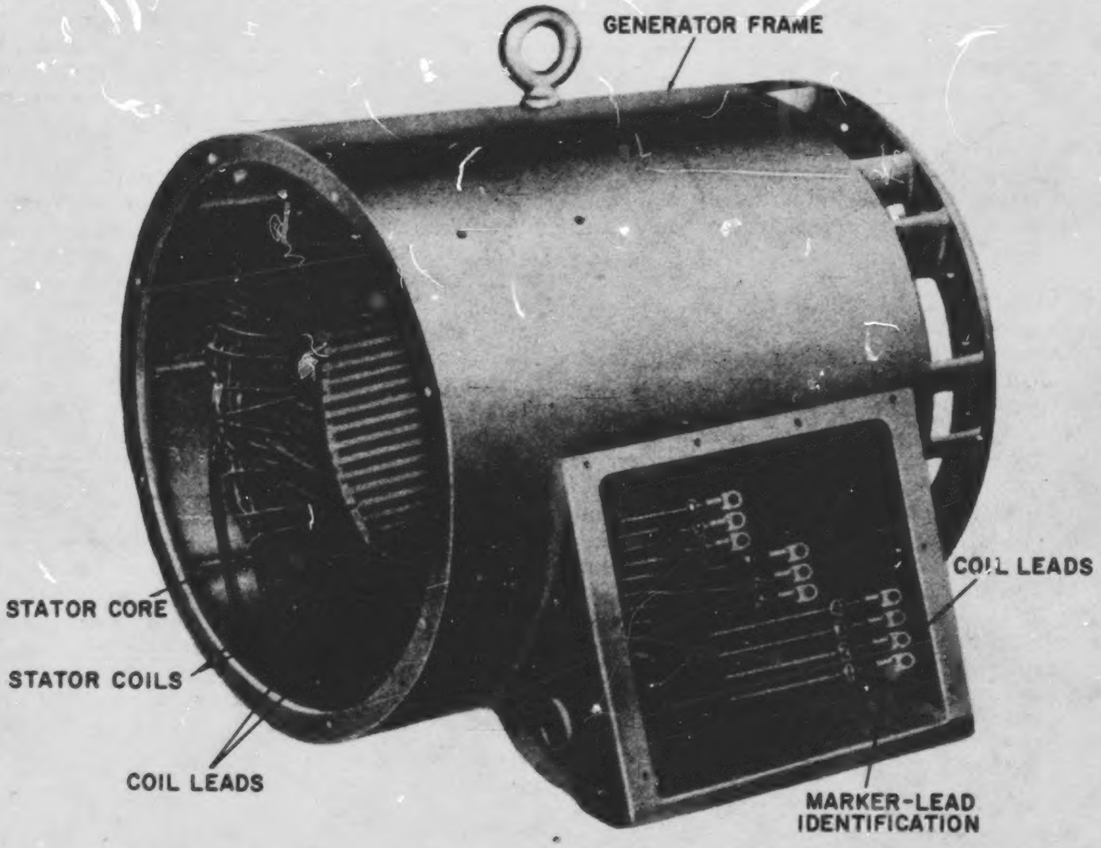
In a dual-voltage, three-phase generator a voltage is generated in each set of coils, when the prime mover is operating at rated speed. Thus, by connecting the external coil leads together in different combinations, you can change the voltage output of the generator. The chart in table 9-2 gives the exact data needed to make these connections for both three-phase and single-phase voltage outputs.

Let's take a specific example. Suppose it becomes necessary to obtain 220 volts single phase from a three-phase, 220/440-volt generator. Checking table 9-2 you find that coil leads T2 and T8 are to be connected together and then in turn, connected, through the main circuit breaker, to one of the two load cables. Similarly coil leads T3 and T9 are to be secured and connected, through the main circuit breaker, to the other load cable. Leads T5 and T6 are connected together as common point. Terminal lugs on the end of each coil lead provide an easy means of bolting them together. Just be



73.68

Figure 9-23. — Welds made by Cadweld process.


GENERATOR FRAME
COIL LEADS
STATOR CORE
STATOR COILS
COIL LEADS
MARKER-LEAD IDENTIFICATION

26.72

Figure 9-24.—Alternator coil leads.

Table 9-2.—Connections for Three-Phase Generators

REQUIRED VOLTAGE	CONNECT LINE LEADS *(via circuit breaker)* TO–			CONNECT	TAPE INDIVIDUALLY
440-VOLTS, THREE-PHASE, 3-WIRE.	T1.	T2.	T3.	T4 TO T7 . . . . T5 TO T8 . . . . T6 TO T9	
127/220-VOLTS, THREE-PHASE, 4-WIRE.	T1 AND T7 . . .	T2 AND T8 . . .	T3 AND T9 . . .	T4, T5, T6, AND T0 FOR NEUTRAL.	
220-VOLTS, SINGLE-PHASE, 2-WIRE.	T2 AND T8 . . .	T3 AND T9 . . .	T3 AND T9 . . .	T5 TO T6	T1, T4, T7, T0.
220/440-VOLTS, SINGLE-PHASE, 3-WIRE.	T3.	T2 AND T9, NEUTRAL.	T8.	T5 TO T6	T1, T4, T7, T0.
440-VOLTS, SINGLE-PHASE, 2-WIRE.	T3.	. . . .	T8.	T2 TO T9 . . . . T5 TO T6	T1, T4, T7, T0.

26.169

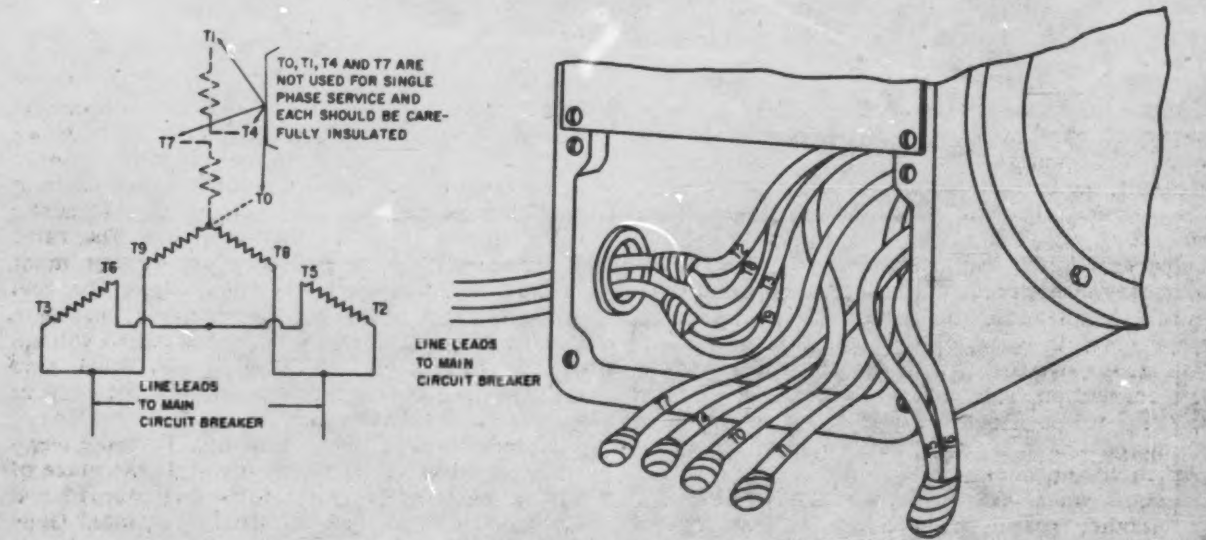
sure that the connections are thoroughly insulated with a wrapping of rubber tape followed by a wrapping of friction tape. Table 9-2 indicates that leads T1, T4, T7, and T0 are not used for single-phase service. Therefore, to finish the job, you should individually insulate each of these four leads with rubber and friction tape. Figure 9-25A shows you how the connections appear on the stator coil diagram. Figure 9-25B shows the appearance of the actual connections.

RECONNECTING GENERATOR LEADS

When you reconnect generator leads to meet certain load conditions, you change not only the voltage output of the generator but also its current rating. These voltage and current changes will have an effect on the operational characteristics of the switchboard controls and instruments. Thus, before the generator can be put into operation, other changes must be made.

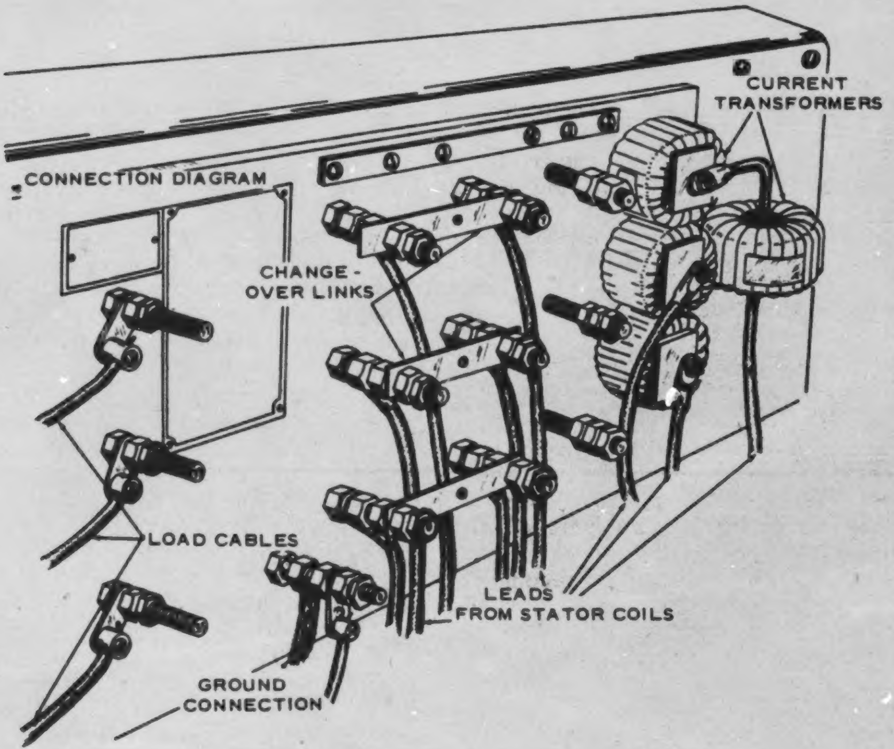
For example, suppose you have to reconnect a 75-kw, three-phase, 220 volt, generator so that it will have an output voltage of 440 volts. In the original setup (220-volt output), the generator was capable of carrying a full-load current of 264 amperes. Changing over to 440 volts, however, reduces its full-load current to 132 amperes. The first thing you will want to check, then, is the fuse rating in the main switch. You will probably find that for the original 220-volt, 264-ampere setup, the generator was protected by a 275-ampere fuse. To protect the generator for its new current rating (132 amperes), you must replace the 275-ampere fuse with one having a 150-ampere rating.

Another thing to consider when reconnecting a generator is the switchboard ammeter instrument that records the current output of the unit. Since it is impractical to use an ammeter capable of carrying the full-load current, instrument transformers are used. An instrument transformer reduces the current value to one that may be safely measured by the ammeter. Usually, the instrument transformer is designed to reduce the full-load current to a secondary current of 5 amperes. In turn, the ammeter, which is connected to the transformer's secondary, is designed to produce a full-scale deflection with an input of 5 amperes. Since the ratio between the load current and the current in the instrument transformer secondary is practically constant, the ammeter scale can be calibrated to read a true value of load current. Now, in the example being used, the generator had a full-load current of 264 amperes when connected for a 220-volt output. That meant


T1
TO, T1, T4 AND T7 ARE NOT USED FOR SINGLE PHASE SERVICE AND EACH SHOULD BE CAREFULLY INSULATED
T7
T4
T0
T9
T8
T6
T5
T3
T2
LINE LEADS TO MAIN CIRCUIT BREAKER
LINE LEADS TO MAIN CIRCUIT BREAKER

26.73

Figure 9-25. — 220-volt, single-phase connections.



26.75

Figure 9-26.—Representative changeover block showing generator and load connecting points.

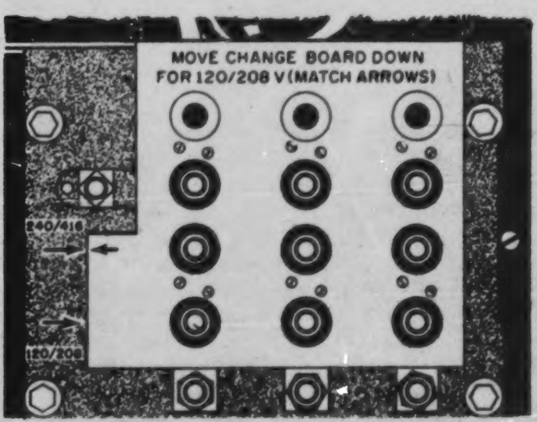
that the instrument transformer induced 5 amperes of current in its full secondary winding when 264 amperes flowed in the line and, as a result, the ammeter had a full-scale deflection. On reconnecting the generator for 440 volts, however, you reduce the full-load current to 132 amperes. Unless you alter the instrument transformer connections, full-load current will produce a half-scale deflection of the ammeter which results in a false reading. In this case, you must move the instrument transformer winding connection from the full-winding position to the mid-tap position. However, most switchboard ammeters have another calibrated scale which makes it unnecessary to apply a correction constant when the current range is changed.

Another possible change in the generator's switchboard wiring concerns the voltage regulator, whose main purpose is to keep the generated voltage within certain limits regardless of changing load conditions. Although there are many types of voltage regulators they all respond to VARIATIONS IN RATED LINE VOLTAGE. However, the line voltage is not applied directly to the regulator unit. A potential transformer is used to reduce the line voltage to a standard value that is safe for the regulator. The ratio of primary voltage to secondary voltage must remain constant if the regulator is to function properly within the limits of the generator's rated voltage. Therefore, when the output voltage of the generator is changed, you must also change the tap connections on the primary of the potential transformer.

Now comes a likely question. To make these changes must you actually dive into the maze of wiring behind the generator's switchboard and move leads from one terminal to another? Generally no. In a few cases you may have to change the leads. Most manufacturers have provided a means to simplify the changeover from one voltage output to another.

One type of changeover device in advanced base generators is shown in figure 9-26. Called a CHANGEOVER BLOCK, it is mounted on the rear of the generator's switchboard (control cabinet). The terminal studs that protrude from the changeover block serve two purposes: they provide a disconnect point between the load cables and the generator coil leads, and they present a convenient means of altering the operating characteristics of the generator's components without changing the positions of the wires. Notice that each of the 10 generator stator coil leads is attached to a correspondingly numbered terminal stud. Rearrangement of the coil leads becomes a simple process of interconnecting the terminal studs in a definite pattern by the use of CHANGEOVER LINKS.

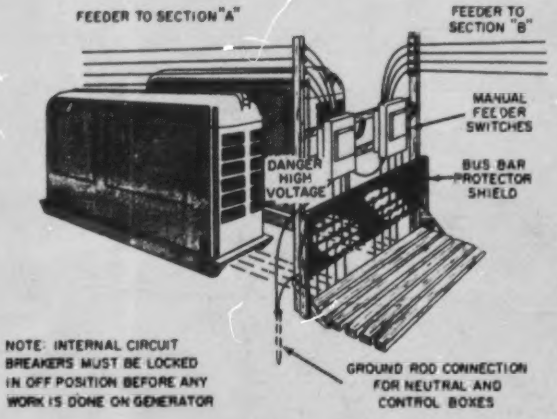
When in position on the coil lead terminal studs, the changeover links also contact other studs that are connected to components, such as the current transformers and the potential transformers. Thus, the outputs of these components are also changed automatically. Connection diagrams on a nameplate attached to the changeover block provide information on the positions of the changeover links for specific voltage outputs.


MOVE CHANGE BOARD DOWN
FOR 120/208 V (MATCH ARROWS)
240/416
120/208

FOR VOLTAGE RECONNECTION, LOOSEN MOUNTING NUTS (12) AND MOVE CHANGE BOARD UP OR DOWN TO ALINE ARROWS INDICATING DESIRED VOLTAGE. INSTALL CHANGE BOARD IN NEW POSITION AND TIGHTEN MOUNTING NUTS.

26.250

Figure 9-27. — Reconnection panel.


FEEDER TO SECTION "A"
FEEDER TO SECTION "B"
MANUAL FEEDER SWITCHES
BUS BAR PROTECTOR SHIELD
DANGER HIGH VOLTAGE
NOTE: INTERNAL CIRCUIT BREAKERS MUST BE LOCKED IN OFF POSITION BEFORE ANY WORK IS DONE ON GENERATOR
GROUND ROD CONNECTION FOR NEUTRAL AND CONTROL BOXES

26.76.1

Figure 9-28. — Representative bus bar installation.

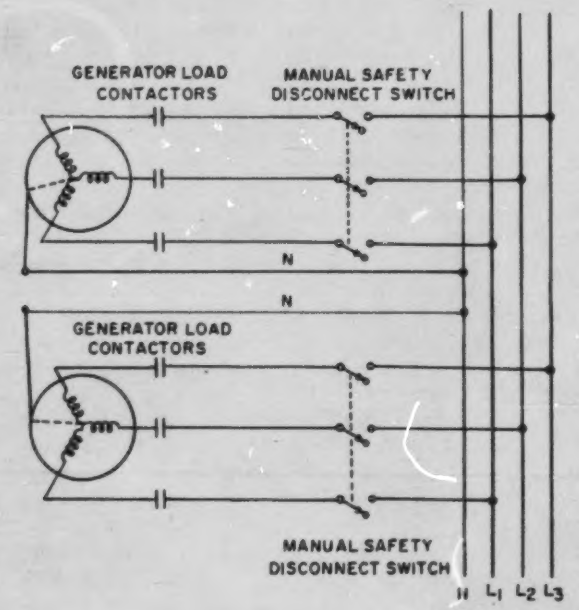
A newer type of changeover board with its instructions is shown in figure 9-27.

Remember that you are responsible for the proper operation of the generating unit. Therefore proceed with caution on any reconnection job. Study the wiring diagrams of the plant and follow the manufacturer's instructions to the letter. Before you start the plant and throw the circuit breaker, double-check all connections.

BUS BAR

There are a number of reasons why sometimes you must use a bus bar when setting up a portable generating station. For one thing, you may not be able to get a generating plant that has sufficient capacity to meet the total power demand of the electrical load. In this case, then, use two or more generating units and collect their paralleled outputs at one central point (the bus bar). Or, you may discover that the electrical equipment in the advanced base is scattered in such a manner as to require the use of feeder (branch) lines that can be controlled from a central source. Again, the bus bar is the answer.

A representative advanced base generating station using a bus bar is shown in figure 9-28 (circuit breakers are enclosed in the generator). Be sure that disconnects are inserted in the installation as shown in figure 9-29. The two generators are leveled on a concrete pad that


GENERATOR LOAD CONTACTORS
MANUAL SAFETY DISCONNECT SWITCH
N
N
GENERATOR LOAD CONTACTORS
MANUAL SAFETY DISCONNECT SWITCH
N
L_1
L_2
L_3

26.76.2

Figure 9-29.—Schematic of bus bar installation.

is sloped for drainage. The electrical output of each generator is transferred underground to the bus bar by four single-conductor cables. The bus bar itself consists of four cables stretched between two 4- by 4-inch posts. A secondary rack mounted on each post serves as an insulating support for the bus bar cables. Two switches, one for each feeder line, are mounted above the bus bar. A wooden platform provides an insulating medium for operating personnel.

Whether or not the schematic of your bus bar installation looks exactly like figure 9-29, the point to remember is that the equipment should be properly secured and supported, and where necessary, properly insulated. The size of wire will depend on the load current. The switches that control the output to each feeder line can be either fused knife switches or circuit breakers. Be sure that the current rating of the fuses or trip elements will provide adequate protection against excessive overloads or short circuits on the feeder lines. Also that the switch blades or breaker contacts are capable of carrying the rated current and voltage of the feeder lines. In addition, protect the switchgear and bus bar from the weather by having a weatherproof canopy built over the rack. The canopy will help ensure uninterrupted service and protect operating personnel.

Improving Power Factor

From your study of basic electricity, you learned that power factor can be improved in parallel circuits by adding capacitors of the proper size in parallel with the load at the points where improvement is needed.

How much capacity to add will generally be figured out for you by someone in operations or the company office.

Generally the most effective location for installation of individual capacitors is as close to the inductive load as possible. This provides maximum power factor correction from the capacitor back to the source of power.

Capacitors should be installed where the temperature of the air does not exceed 104° (40° C). They should always be well ventilated because they always operate at full load and generate heat which must be removed.

Most power capacitors are provided with fuses which provide protection in case of an internal short circuit. An accepted method of wiring capacitors is illustrated in figure 9-30, where a separate service switch is used.

Capacitors can be mounted on the floor, wall or ceiling, depending on the floor space and equipment layout. Most come equipped with mounting brackets, so that they can easily fit into these places.

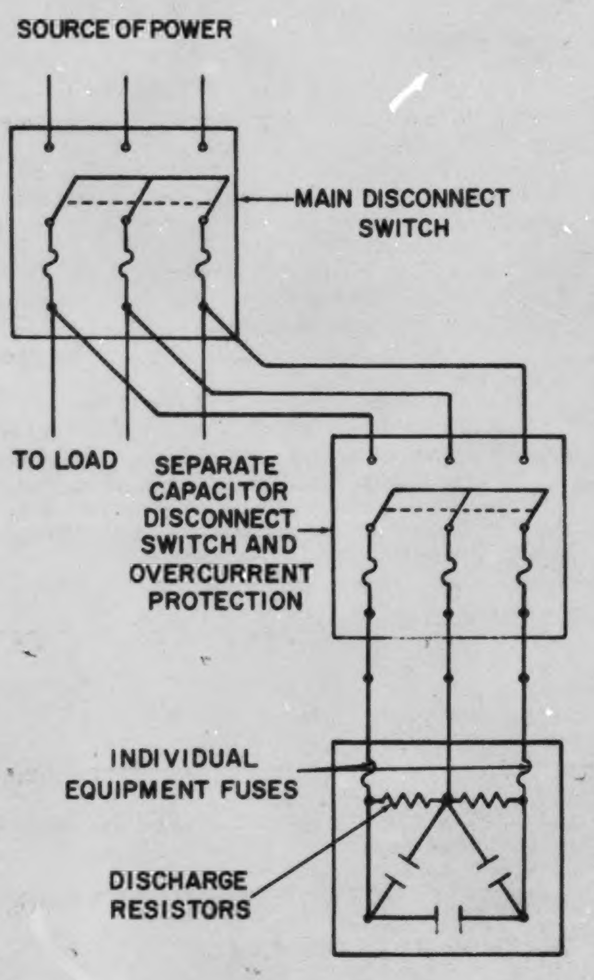
AN IMPORTANT SAFETY PRECAUTION IS THAT A 5 MINUTE WAITING PERIOD MUST BE OBSERVED BEFORE ANY WORK IS DONE ON A DISCONNECTED CAPACITOR. Since a disconnected capacitor may retain its electrical charge and have full line voltage across its terminals, these terminals must be short circuited and grounded before any work is begun.

PREPARING TO OPERATE THE GENERATOR SET

After setting up a portable generator set, you must do some preliminary work before placing it in operation.

INSPECTING THE GENERATOR

First make a visual overall inspection of the generator. Look for broken or loose electrical and hose connections, and for loose bolts


SOURCE OF POWER
MAIN DISCONNECT SWITCH
TO LOAD
SEPARATE CAPACITOR DISCONNECT SWITCH AND OVERCURRENT PROTECTION
INDIVIDUAL EQUIPMENT FUSES
DISCHARGE RESISTORS

73.343

Figure 9-30.—Capacitor installation with overcurrent protection.

and capscrews. See that the set is properly grounded. Check the wiring diagrams in the instruction manual furnished with the generator, to see if any wire connection is suspected of being improperly connected. Any faults that are found should be corrected immediately.

SERVICING THE PRIME MOVER

Servicing the prime mover is the next step in the process of placing the generator in operation. Be sure that the crankcase is filled with the proper grade of oil and lubricant. A lubrication chart in the instruction manual furnished with each generator will show the proper grade of oil to use at the operating temperature. Regardless of the air temperature, be sure to use an antifreeze solution in the proportions recommended in the instruction manual for the generator.

The fuel tank should be filled with clean fuel oil, strained if necessary.

Prime movers of advanced base electric power generators are started by starting units which obtain their power from batteries. If your prime mover is equipped with a battery (or batteries) you have another servicing job to do. Batteries are usually shipped without the electrolyte, but with the plates in a dry-charged condition. Thus, it is necessary to fill the battery with electrolyte. Usually, the electrolyte is shipped right with the generator and is of the correct specific gravity.

If you must prepare your own electrolyte, however, consult a mixing chart (table 9-3). In this case, use the specific gravity value recommended in the instruction manual.

CAUTION

BE SURE TO ADD THE ACID TO THE WATER S-L-O-W-L-Y, STIRRING CONSTANTLY AND THOROUGHLY.

Table 9-3.—Electrolyte Mixing Chart

SPECIFIC GRAVITY DESIRED	USING 1.835 SPECIFIC GRAVITY ACID		USING 1.400 SPECIFIC GRAVITY ACID	
	PARTS OF WATER	PARTS OF ACID	PARTS OF WATER	PARTS OF ACID
1.400	3	22	..	..
1.345	2	1	1	7
1.300	5	2	2	5
1.290	8	3	9	20
1.275	11	4	11	20
1.250	13	4	3	4
1.225	11	3	1	1
1.200	13	3	13	10

26.164

After the electrolyte has been prepared, again see the instruction manual for the recommended filling procedure. If the manual is not available, follow this general procedure: First, add electrolyte to each of the battery's cells until the level of the electrolyte is visible in the filler neck or at least 3/8 inch above the separators. The temperature of the electrolyte when placed in the cells should be between 60° and 90° F. IT SHOULD NEVER EXCEED 90° F.

Chemical reaction resulting from adding electrolyte will cause the battery to heat. Cool it artifically (cooling fans) or allow to stand at least 1 hour before placing it in service.

You will probably notice at the end of the cooling period that the level of the electrolyte has dropped due to the electrolyte soaking into the plates and separators. Before placing the battery in service restore the electrolyte to its proper level. Remove any electrolyte spilled on the battery, using a cloth dampened with a solution of bicarbonate of soda and water.

Although the battery can be placed in service 1 hour after filling it with electrolyte, do so only in an emergency. If at all possible, give the battery an initial light charge.

If the instruction manual is not available or if it does not give the battery charging procedure, proceed as follows:

Charge the battery at a low rate (about 5 amperes) until the voltage and specific gravity, corrected to 80° F, remains constant for at least 5 hours. If the temperature of the electrolyte reaches 125° F reduce the charging rate or stop the charge until the battery cools. NEVER PERMIT THE TEMPERATURE TO EXCEED 125° F. During charging, replenish any water lost by evaporation.

After the battery has been charged, connect it into the starting system of the prime mover as indicated by the wiring diagrams accompanying the generator.

On large generators you should check the area ventilation; the fan cover must be opened and latched in that position. There must be no cover or obstructions over the main diesel engine exhaust stacks, or over the radiator section. The bypass shutters or doors may be closed to shorten the warming-up period, and roof hatches and side louvers MAY be opened for additional ventilation, if required.

SERVICING THE GENERATOR

Just as important as the preparation of the prime mover is the inspection and servicing of the alternator. Generally, you should take the following steps:

1. Find all the electrical connections by referring to the generator's connection diagrams and see that the connections are tight.

2. See that the collector rings are clean and have a polished surface.

3. Check collector brushes to make sure they have no tendency to stick in the brush holders, that they are properly located, and that the pigtails will not interfere with the brush rigging.

4. Check the collector brush pressure, making sure it agrees with the pressure recommended in the manufacturer's instruction manual. Calculations for brush pressure may be made, using a spring scale (to measure the spring tension) and the formula:

$$\frac{\text{Pressure}}{\text{(psi).}} = \frac{\text{Tension (in pounds)}}{\text{Brush width x Thickness (inches).}}$$

Example:

Manufacturer's recommended tension = 40 ounces (2.5 pounds)
Brush width = 1/2 inch
Brush thickness = 1-1/8 inch

Substituting those figures in the formula above,

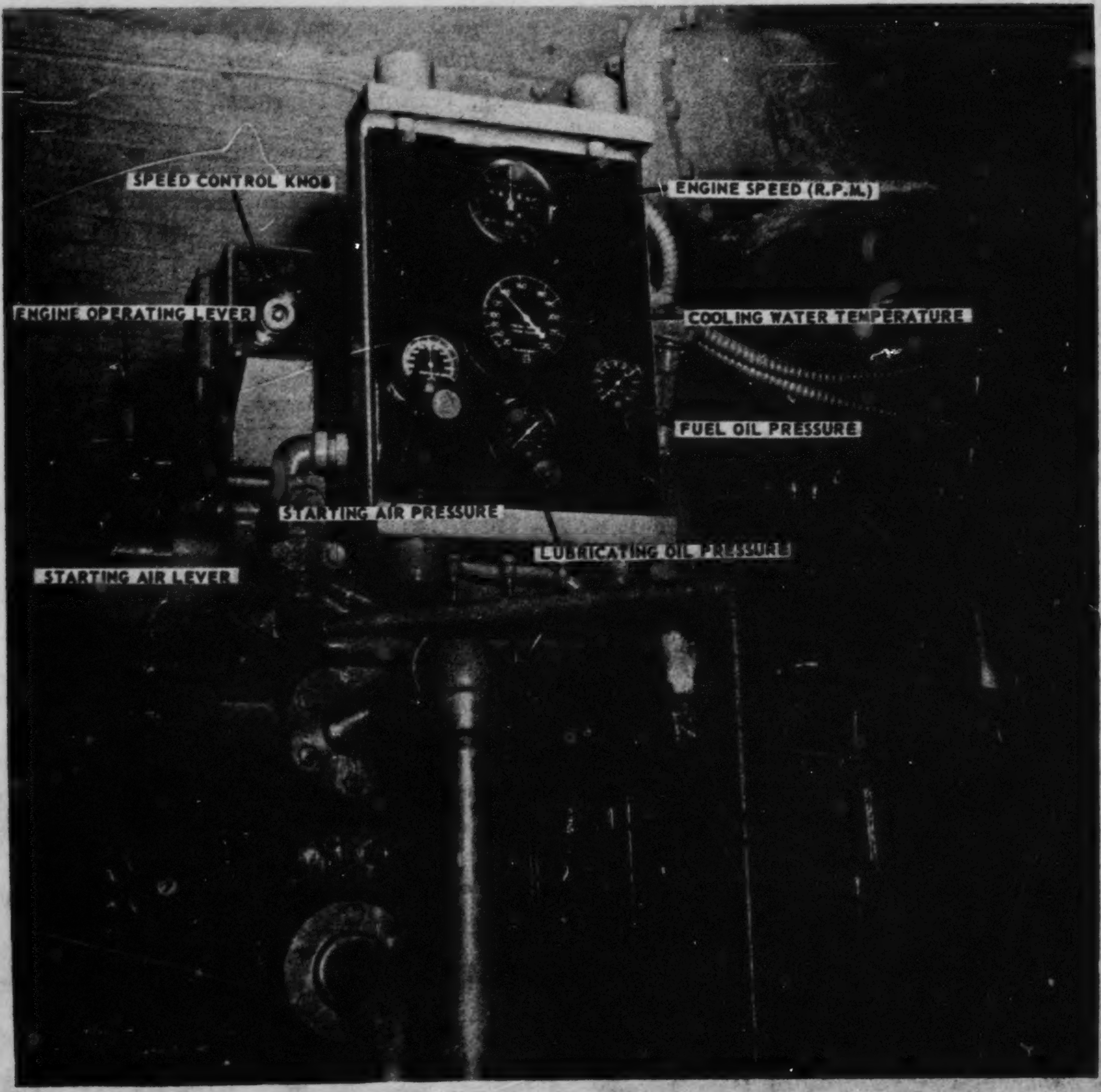
$$\text{Pressure} = \frac{2.5 \text{ pounds}}{0.5 \times 1.125} = 4.4 \text{ psi}$$

SERVICING AND OPERATING PROCEDURES

You must always check the appropriate instruction manual for specific operating and servicing procedures. The following information, however, is general and applicable to the generators you may encounter.

Make sure that the fuel you are going to use is not contaminated with dirt or water, and that all equipment (cans, funnels, and/or nozzles) for transferring the fuel to the engine fuel tank is clean. Dirty fuel clogs the carburetor and fuel lines.

Water in the fuel often keeps an engine from starting and damages the injection pumps and nozzles of diesels. In cold weather, especially,


SPEED CONTROL KNOB
ENGINE SPEED (R.P.M.)
ENGINE OPERATING LEVER
COOLING WATER TEMPERATURE
FUEL OIL PRESSURE
STARTING AIR PRESSURE
LUBRICATING OIL PRESSURE
STARTING AIR LEVER

73.58

Figure 9-31.—Diesel engine, showing controls and gages.

fuel tanks should be kept full to minimize condensation of moisture in them.

BE SURE THE FUNNEL IS IN DIRECT CONTACT WITH THE TANK when fuel is being transferred, to eliminate the possibility of an explosion.

Damage due to dirt can be eliminated or minimized by changing the air cleaner at appropriate intervals. If the oil feels gritty when checking its level, change it and the filter too.

If your generator set requires water for its cooling system, be sure to keep it filled. Remember, that in freezing temperatures, antifreeze must be added.

Check the battery electrolyte level periodically and add water if required. When available, distilled water is preferable to plain water. Coat the battery terminals with a light coating of corrosion-preventive grease after connections have been tightened.

OPERATION OF POWER STATION

Once the central power station has been established, the various base activities should be able to count on a continuous and adequate flow of electric current to supply the needs of the living and working spaces. As a Construction Electrician who has worked on the installation of the power distribution system, you will have a good overall working knowledge of this system. However, you should also know how to operate and maintain the equipment in the power generating station.

You can help yourself to the required know-how by studying the general operating and maintenance procedures in this chapter, by referring to electrical plans and diagrams relating to tasks involved, and by consulting the instruction manual furnished with each piece of plant equipment.

STARTING AN A-C GENERATOR

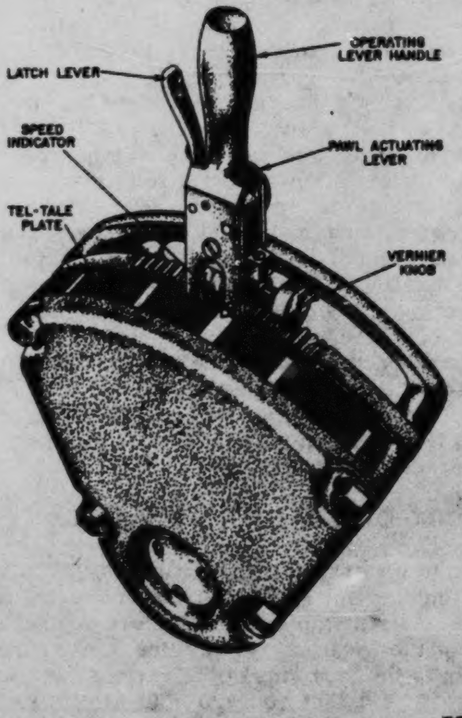
The following description of the steps in starting an a-c generator is a general description only. For a particular generator you follow the step-by-step instructions for starting given in the manufacturer's manual.

It is assumed that the generator is driven by a diesel engine which is started by air pressure (some diesels are started by an electric starting motor and batteries or by a gasoline engine which is cut off after the diesel engine starts running on its own fuel).

Figure 9-31 shows the controls and gages of a diesel engine that drives a large generator. The STARTING AIR LEVER controls a valve which admits starting compressed air to the engine cylinders. The ENGINE OPERATING LEVER controls engine speed while starting, stopping, or in an emergency. The SPEED CONTROL KNOB controls engine speed during normal operation. Figure 9-32 shows details of the engine operating lever.

The speed control lever controls engine speed during normal operation through a governor. In starting, the governor is made inoperative so that the operator can control engine speed during starting by manipulating the engine operating lever. To render the governor inoperative, you set the PAWL-ACTUATING LEVER (fig. 9-32) in the position where it points away from the engine. After the diesel engine starts, you turn the pawl-actuating lever toward the engine.

Before you start the diesel engine, see that the circuit breaker and the field switch on the



73.59

Figure 9-32.—View of diesel engine operating lever, showing details.

generator switchboard are in the OFF position. This step ensures that no load exists on the generator. Next, set the pawl-actuating lever for manual control (away from the engine), and latch the engine-operating lever in the INJ FULL position (fig. 9-32).

The LATCH LEVER shown in figure 9-32 releases (by squeezing) the engine-operating lever for movement to a different position, and locks the same in the new position when the latch lever is released.

The VERNIER KNOB of figure 9-32 is used to control speed adjustment when you are operating the engine under manual speed control, as in an emergency.

Pull down on the starting air lever (fig. 9-31). This will admit air to the cylinders, which will in turn set the pistons in motion. The engine should fire within 10 seconds; when it does, release the starting air lever.

Immediately after the engine fires, check the LUBRICATING OIL PRESSURE GAGE (fig. 9-31). If it does not indicate oil pressure within 10 seconds after the engine fires, stop the engine at once by moving the engine-operating lever to the INJ STOP position (fig. 9-32).

If lubricating oil pressure is satisfactory, turn the pawl-actuating lever toward the engine and move the engine-operating lever to the GOV RUN position. Engine speed is now controlled by the governor.

Make sure you know the engine speed required to maintain the required voltage output. Assume that to produce a 60-hertz voltage, the engine must make 600 rpm. Check the rpm indicator and if it does not read 600 rpm, turn the SPEED CONTROL KNOB in the appropriate direction until the engine speed indicator reads 600 rpm.

Recheck the lubricating oil gage for proper oil pressure; also check the FUEL OIL PRESSURE GAGE for proper fuel oil pressure, and the COOLING WATER TEMPERATURE gage for proper water temperature (fig. 9-31).

PLACING GENERATOR ON THE LINE

Your generator is now running, but it is not yet "on the line", that is, not delivering power to the distribution system. Before you set about putting the generator on the line, make sure that you know the locations of the various switchboard controls, and that you are able to operate them smoothly and in proper sequence; check to see that the voltage regulator switch is in OFF (or MANUAL CONTROL) position, and that the voltmeter selector switch is set to permit the a-c voltmeter to indicate the desired measurement.

Turn the handle of the exciter field rheostat counterclockwise as far as it will go, so as to put maximum resistance into the shunt field of the exciter.

Throw the field switch to the ON position, thus making exciter voltage available to the generator field. At the same time watch the a-c voltmeter and ensure that it records a low reading.

Turn the exciter field rheostat knob clockwise, thus decreasing exciter field resistance, and increasing exciter field voltage and excitation current in the generator's field winding. This will cause output voltage to rise. Watch the a-c voltage meter, and turn the rheostat knob until the rated voltage is reached.

Check the frequency reading on the frequency meter. Increase or decrease the engine speed until you read normal frequency (in this case, 60 hertz).

Turn the voltage regulator switch to the ON or AUTOMATIC position, thus placing the voltage regulator in control. Then check the voltmeter to ensure that it still reads rated voltage value. If the value has changed, adjust the voltage regulator rheostat until the voltmeter again reads rated value.

Release the interlock on the circuit breaker, thus closing the generator circuit and energizing the bus. With the generator now connected to the external circuit, the a-c ammeter will indicate the current drawn by the load.

Check the current in each phase by switching the ammeter. Recheck the voltage across each phase.

SYNCHRONIZING GENERATORS

The load power demand may often reach a point where it cannot be satisfied by a single generator. In this case, it becomes necessary to "cut in" or "parallel" another generator—that is, add another generator to the bus. You CANNOT parallel by simply starting the engine of a reserve generator and place this generator on the line by throwing the main switch. You must go through a procedure that concerns four important events: (1) The incoming generator voltage must equal the bus voltage. (2) It must have the same frequency and (3) must be in phase with the bus voltage. (4) All phases must be connected in proper sequence. This procedure is called synchronizing or paralleling generators.

To adjust frequency,—you adjust the speed in rpm of the prime mover—thereby ensuring that the difference in potential between CORRESPONDING terminals of the two generators is zero. Watch the voltmeters on the two units until they read the same. To bring the incoming generator into phase with the voltage on the bus, you will either use a lamp method or a synchroscope of synchronizing lamps. In paralleling generators, you will either use a lamp method or a synchroscope.

Lamp Synchronizing Methods

The most satisfactory method of synchronizing generators, using lamps, is the two-bright one-dark method of figure 9-33. Note that the lamps are connected directly between the incoming generator's output and the buses.

In this way, the two a-c sources may be synchronized before the incoming generator's main power contactor is closed. At the instant the two generators are to be paralleled, L_2 and L_3 will glow with maximum brilliance and L_1 will be dark.

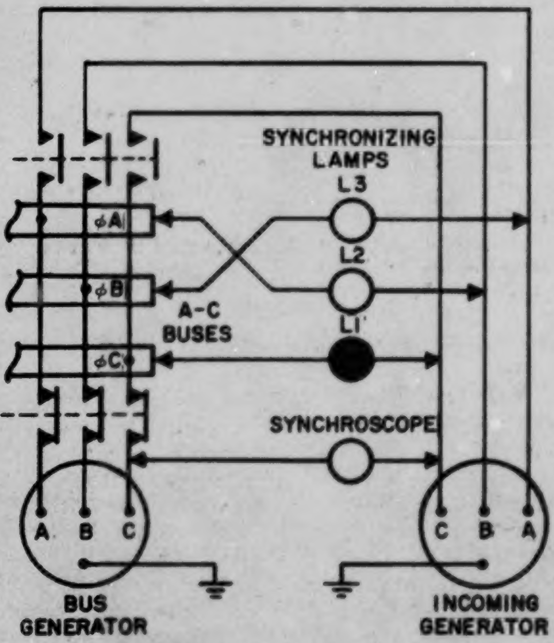


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Figure 9-33.—Synchronizing lamp connection for two-bright one-dark method.

Assume that the incoming generator is far out of synchronism—lagging. All three lamps will appear to glow steadily, because the frequency of the voltage across them is the difference in the frequencies of the two generators, and thus is too high for individual alterations to be observed. As the lagging generator is accelerated, however, the lamp (differential) frequency decreases until their light flickers visibly. Their flickering will have a rotating sequence, if connections are correct, and will indicate which generator is faster.

At a point approaching synchronism, lamp L_1 will be dark because it is connected between like phases. That is, the two phase C voltages will be so nearly synchronized that their differential voltage across L_1 will be insufficient to make it glow visibly. However, this differential may still be of sufficient magnitude to damage the generators should they be connected at this time. The reason for cross-connecting L_2 and L_3 is now indicated. Under perfectly synchronized conditions, the phase voltages across L_2 and L_3 are both 120° apart, because of their cross-connection, and both glow with equal brilliance. However, if the generators are not in complete synchronism, but only very near it, one of the bright lamps would be increasing in voltage as the other was decreasing. This action would cause a visible difference in the brilliance of L_2 and L_3. Thus, by adjusting the incoming generator's frequency so that no visible difference of brilliance exists between L_2 and L_3, the exact point of synchronism can be approached very closely before paralleling the incoming generator with the generator on the bus.

Two other methods are used, one is called the "all-dark" method, the other, the "bright-lamp" method.

In the all-dark method of synchronizing, lamps are connected across an open three-pole switch between the bus and the incoming generator as shown in figure 9-34. If the lamps increase and decrease in brilliance together, the phase sequences of the two generators are the same. If the lamps rotate in brilliance, the phase sequences are not identical. Interchanging any two of the three leads from the incoming generator will obtain the correct phase sequence. Be sure the lamps have a voltage rating twice the generator terminal voltage. If lamps of this voltage rating are unavailable, several lamps in

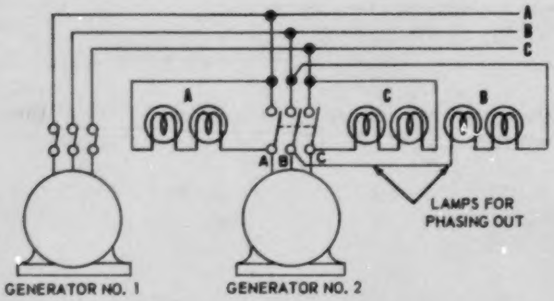

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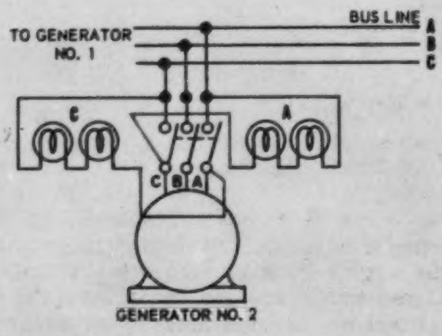
Figure 9-34.—The all-dark synchronizing method.

series, voltage dropping resistors, or stepdown transformers must be used. When the lamps are dark the voltages are in phase and the paralleling breaker may be closed.

The "bright-lamp" method is more sensitive and is used for large, high-speed generators. The arrangement of lamps is shown in figure 9-35. When lamps A and C burn with the same brilliancy the unit is in phase. As one of the two increases in brilliancy and the other decreases, the instant of synchronism is the instant when they match in brilliancy. The sequence of brightness of the lamps indicates whether the incoming alternator is fast or slow. It is standard practice to close the generator breaker when the incoming alternator's frequency is slightly ahead of that of the already operating alternator.



73.61
Figure 9-35.—The bright lamp synchronizing method.

Synchronizing With Synchroscope

The sequence of operations in paralleling two alternators by synchroscope follows.

Compare the bus voltmeter reading (voltage produced by the already operating generator) with that on the incoming generator voltmeter. If the readings are not the same, adjust the voltage regulator rheostat of the incoming generator until its voltage is equal to the bus voltage. This is an important step, because unequal voltages will cause circulating currents to flow between the parallel generators.

Compare the frequency of the incoming generator with that of the bus, and adjust to correspond by means of the incoming generator's governor motor-control switch.

Turn the synchronizing switch to the ON position. The synchroscope will rotate in one direction or the other. (If the switchboard is also equipped with synchronizing lamps, they will increase and decrease in brilliancy.)

Use the governor motor control switch to adjust the speed of the incoming generator until it is operating at approximately the same frequency as the bus voltage. This will be indicated by the synchroscope rotating slowly in the FAST direction. (The synchronizing lamps will slowly increase and decrease in brilliancy.)

Make sure the voltages of bus and incoming generator are the same. Then, JUST BEFORE the synchroscope pointer passes through the zero position, close the incoming generator's breaker and thus "cut in" the generator.

After the incoming generator has been thus "cut in" to the bus, there are two additional adjustments that must be made. One of these ensures that each generator is carrying its share of the kilowatt load. The other ensures that each generator is operating with the same power factor.

The division of kilowatt load between a-c generators operating in parallel depends on the relative setting of their engine governors. Equalizing power factor means ensuring that each generator is producing its share of wattless current or "reactive kva." The amount of reactive kva two generators supply depends on the relative setting of their voltage regulators. Therefore, to adjust the generators for parallel operation you take the following steps.

Turn the governor motor control switches until the wattmeters of the generators read the same (if the generators have the same rating), or until the load is proportionally divided (if the generators have different ratings). The load is increased on a too lightly loaded generator by increasing engine speed, on a too heavily loaded generator by decreasing engine speeds. These adjustments must be made simultaneously, to maintain constant frequency.

To balance reactive load, turn the voltage regulator rheostat of each generator until the power factor meter reading is the same for each, indicating that the burden of reactive kva is being properly shared. If the switchboard is not equipped with power factor meters, the a-c ammeter of each generator can be used. Proper adjustment exists when the ammeters show equal currents for generators of the same rating, or proportionally equal currents for those of different ratings.

The direction in which you turn the voltage regulator rheostat of each generator depends on the reading of the generator's power factor meter or ammeter before the adjustment is made. The voltage should be decreased on the generator carrying too much power factor, increased on the one carrying too little.

After closing the main breaker, observe the a-c ammeters of equal generating units to ensure that they read the same. Unequal readings mean that one generator is doing more work than the other. You can even out the load by increasing the speed of the generator having the lower ammeter reading. Adjust the control governor motor until both a-c ammeters read the same.

SECURING GENERATORS

When a SINGLE generator, connected alone to a bus, is to be taken out of operation, proceed as follows:

- Remove as many individual loads as possible to reduce arcing and damage to the line switch or circuit breakers when the circuit is opened. Open the feeder breakers to further reduce the generator load as much as practicable.

- Trip the generator circuit breaker.

- Turn the voltage regulator switch to the OFF or MANUAL position.

- Turn the handle of the exciter field rheostat counterclockwise, as far as it will go, thus cutting in all resistance to the exciter field and decreasing the voltage to the exciter field.

CAUTION: The field circuit of a generator which is to be disconnected from the bus bars must not be opened before the main breaker has been opened. If the field circuit is opened first, a heavy current will flow between the armatures.

- Move the governor control lever to the low idle engine speed and run the engine about 5 minutes until it cools down.

- Stop the prime mover by moving the engine operating lever to the GOV STOP position (fig. 9-32).

It may be necessary to secure a generator which is operating in parallel with another. The typical situation is one where a peak load (as when darkness falls and many lights come on) occurs and then passes. When the load comes on, another generator is cut in; when it passes, the generator is secured.

Before you remove the generator power from the bus, it is very important that you shift the kilowatt load being carried by the generator which will be cut out to the generator or generators which will remain on the line. This shift of kilowatt load is accomplished by turning the governor motor control switch of the generator to be secured to LOWER, and the same switches on the remaining generators to RAISE. The wattmeters on the switchboard will indicate how the shift is progressing and when it is completed.

When the load has been shifted, trip the circuit breaker on the generator which is to be taken out, and then secure that one as you would a single generator.

A generator which has been operating under a heavy load should not be shut down until it has been run on a light load for a few minutes to reduce temperatures.

EMERGENCY SHUTDOWN

In the event of engine overspeed, high jacket water temperature, or low lubricating oil pressure, the engine may be shut down and disconnected from the main load by tripping the main circuit breaker. In addition, an indicator may light or an alarm will sound to indicate the cause of shutdown. After an emergency shutdown and before the engine is returned to operation, the cause of shutdown should be investigated and corrected. NOTE: It is important to check the safety controls at regular intervals to determine that they are in good working order.

OPERATING RULES

The orders posted in the station for the guidance of the watchstanders should include a general list of operating rules and electrical safety precautions. MAKE SURE YOU CARRY THEM OUT! Here are a few simple, but important, operating rules.

Watch the switchboard instruments. They show how the system is operating, reveal overloads, improper division of kilowatt load or of reactive current between generators operating in parallel, and other abnormal operating conditions.

Keep the frequency and voltage at their correct values. A variation from either will affect, to some extent at least, the operation of the base's electrical equipment, especially teletypewriters and electric clocks.

USE GOOD JUDGMENT WHEN RECLOSING CIRCUIT BREAKERS AFTER THEY HAVE TRIPPED AUTOMATICALLY. Generally the cause should be investigated if the circuit breaker trips immediately after the first reclosure. However, reclosing the breaker a second time may be warranted if power has to be restored immediately. Don't forget, repeated closing and automatic tripping may damage the circuit breaker and thus increase the repair or replacement work.

Don't start a plant unless all its switches and breakers are open and all external resistance is in the exciter field circuit.

Don't operate generators at continuous overload. Record the magnitude and duration of the overload in the log; record any unusual conditions or temperatures observed. Readings taken over a period of time may show a trend, such as decreasing oil pressures or increasing engine temperatures, that points to a trouble or fault.

Don't continue to operate a vibrating machine. Find and correct the cause; then record the cause in the log.

GENERATOR WATCH

Constant, around-the-clock attention must be given to the generators at a central power station that is required to supply a continuous and adequate amount of power. The 24-hour period is divided into a number of watches: the number depends, of course, upon the personnel available for this type of duty.

At most stations, 6-hour watches are the common practice. An 8-hour watch schedule does not ordinarily work a hardship, but watches of more than 8 hours should be avoided except in an emergency.

Besides operating the generating equipment, watchstanders must keep the daily operating log, do housekeeping chores, and the generating equipment.

Keeping a Station Log

A station log is a written record which serves a number of purposes. For one thing, it indicates when various equipment units require periodical maintenance work or replacement. A series of entries can often pinpoint signs of breakdown when the breakdown occurs so gradually that it never becomes an obvious problem at any particular instant.

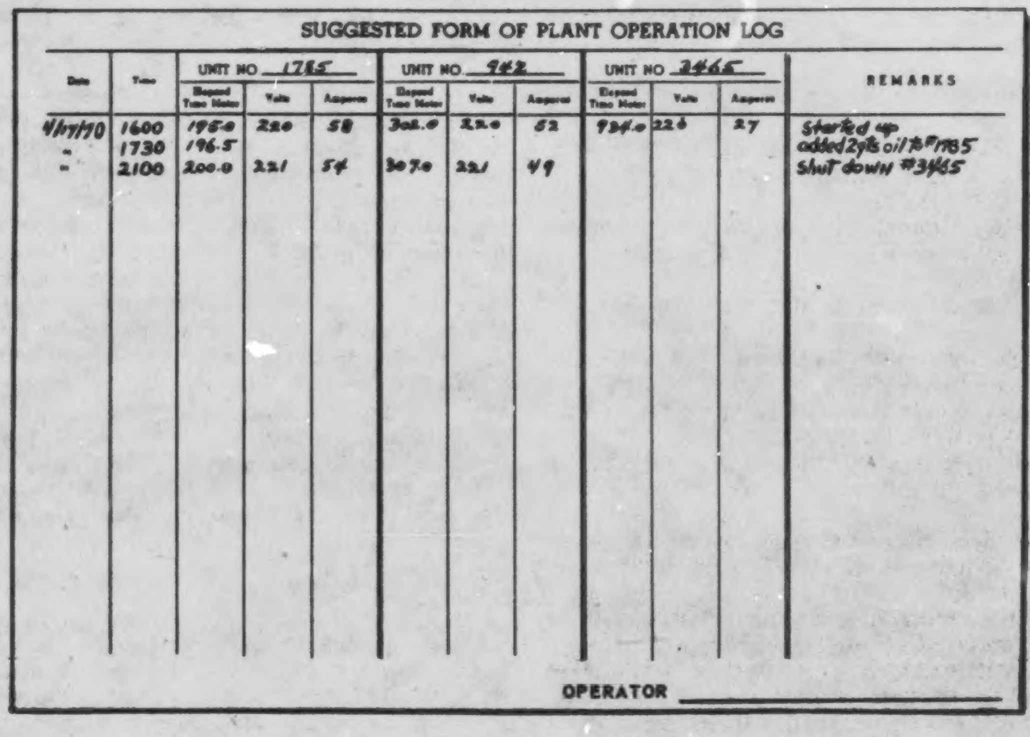
With a great many items of complex equipment working together to produce heat, light, and power for an entire base, it is vital that each item of this equipment be kept operating satisfactorily. A well-kept log is an important means for alerting a trained man to the first signs of trouble.

The form used for log entries varies with the views of the supervisory personnel in different plants, and there is no standard form to be followed by all stations. Regardless of form, any log must describe the hourly performance, not only of the generators, but also of the numerous indicating and controlling devices.

Figure 9-36 shows one type of log that may be kept on the generator units of a power plant. This is only a suggested form, of course, and there may be at your station many other items to keep a record on.

Housekeeping

As a watchstander keep your duty station clean and orderly. Also keep in their proper places tools and auxiliary equipment that are not being used. Store clean waste and oily waste in separate containers. OILY WASTE CONTAINERS MUST BE KEPT COVERED. Empty oily waste containers at least once a day to reduce fire hazards. Care given the station floor will depend on its composition. Generally,



SUGGESTED FORM OF PLANT OPERATION LOG

Date	Time	UNIT NO 1785			UNIT NO. 942			UNIT NO 3465			REMARKS
		Elapsed Time Meter	Volts	Amperes	Elapsed Time Meter	Volts	Amperes	Elapsed Time Meter	Volts	Amperes	
4/17/70	1600	195.0	220	58	302.0	220	52	934.0	220	27	Started up
"	1730	196.5									added 2 qts oil to #1785
"	2100	200.0	221	54	307.0	221	49				Shut down #3465

OPERATOR ________________

73.57

Figure 9-36.—Representative generating station operator log.

it should be swept down each watch. Remove at once any oil or grease that is tracked around the floor.

Operator Maintenance

Since there are many different types of generators, you should consult the manufacturer's instruction manual for details concerning maintenance of your equipment. SAVE THIS INSTRUCTION MANUAL! Additional copies are rarely available.

The lubrication and maintenance schedule taken from an instruction manual follows:

1. Grease fuel transfer pump every three months.
2. Grease generator yearly with Mil-G-10924 grease.
3. Change oil in air cleaner every 50 hours of operation. Oil in oil bath air cleaner should be changed every time the oil is changed in the engine crankcase. The oil level of the air oil bath filter should be checked daily. Operation of the unit in extreme dust conditions necessitates more frequent maintenance on oil bath air filters.
4. Grease water pump belt tightener idler pulley.
5. Replace brushes if less than 1/4" long.
6. Every three months, clean load contactor faces (do not file); check all connections for tightness and wipe magnet faces clean.
7. Inspect pole shader every three months and replace if cracked or broken.
8. Set battery charger timing relay to 24 hour position monthly.
9. Renew element and reassemble oil filters every 50 hours of operation.
10. Drain and refill engine crankcase with MIL-L-9000 lube oil every 50 hours of operation.

Observe all safety precautions. Safety warnings, such as keeping the funnel in contact with the fuel tank when filling with gasoline, might save a life. Here are some general daily maintenance and routine practices.

- Check the following:
  - Level of coolant
  - Radiator and coolant hoses for leaks
  - Battery electrolyte level
  - Fuel tank for leaks
  - Free movement of radiator shutters
  - All switches for proper operation
- Bring oil level to high mark on dipstick.
- Drain water and sediment from strainers.
- Drain water from fuel tank.
- Fill fuel tank as required with appropriate diesel fuel.
- Connect battery charger to utility source if unit is not operating.

The use of daily, weekly, monthly, and other periodic inspections and preventive maintenance programs rigorously enforced will minimize down-times of your equipment and help keep your equipment operational for longer periods of time.

SWITCHGEAR MAINTENANCE

At least once a year, a check should be made of the switchgear component, with careful attention given to the following factors.

General cleaning of the component parts is essential. The front panels of dead-front switchboards can be wiped off with a dry cloth. A metal-covered switchgear can be opened and inspected for surface cleanliness. Before any work is done on live parts, however, deenergize the switchboard. Wipe all dust from bus bars and insulating material.

Inspect electrical connections and mechanical fastenings. Do not limit this check to a sight inspection, but touch and shake the various parts to make sure that all connections are tight, and all mechanical parts free to function properly. Pay special attention to the bolted joints of the bus bar, because a loose joint can cause overheating.

Examine all meters and instruments mounted on the switchgear panels. Look for cracked or broken glass, or signs of damage to the cases. Adjust the pointer of each instrucment, so that it reads zero when the instrument is not energized.

Examine all indicating lamps, to make sure that none are burned out.

Inspect all instrument transformers mounted on the switchboard. To be in good condition, an instrument transformer must have all primary and secondary connections tight, and all grounding connections intact. Potential transformer fuses must make firm contact in their clips.

Check the condition of all rheostat mechanisms. Replace broken or burned-out resistors. If no replacements are available, make temporary repairs by bridging the burned-out sections. Check to see that there is nothing to block the ventilation of rheostats and resistors.

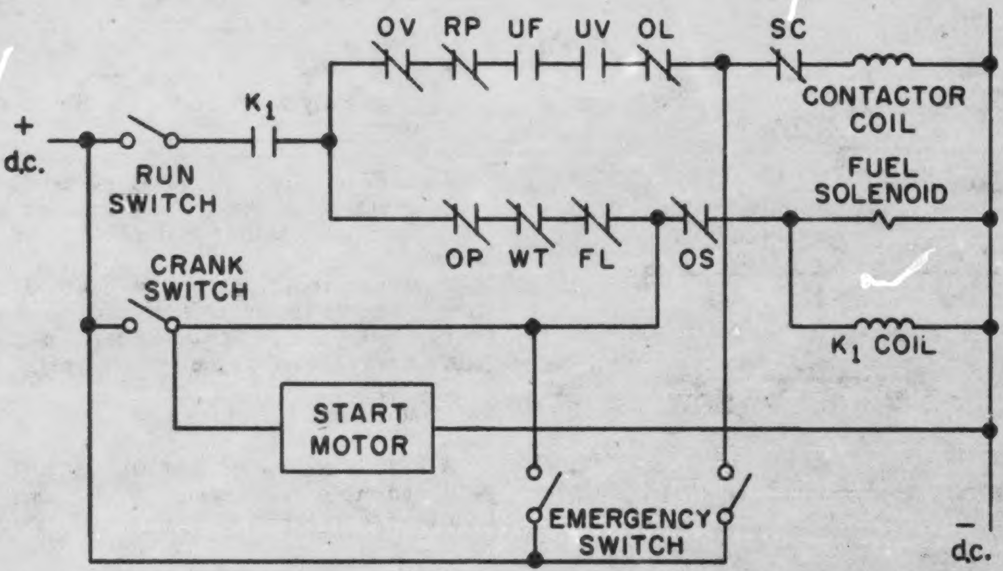
Test the operation of switchgear position-changing mechanisms, such as the lowering and raising mechanisms, and the pullout devices of the circuit breakers used in metal-clad switchgear.

SAFETY DEVICES AND INDICATORS

Many generator sets are equipped with various safety devices to protect the equipment from damage. These include low lube oil pressure, high coolant temperature, overspeed, overcurrent and reverse current, undervoltage and overvoltage relays. When a fault occurs, the generator is usually caused to shut down by appropriate automatic switches. Additionally, indicator lights come on making diagnosis of the cause of the fault easier. For example, when the oil pressure gage falls below 10 psi (pounds per square inch) in one generator, the main contactor opens to shut the engine off, and the low lube oil pressure indicator bulb lights up. Take advantage of the help provided by these indicators. Train yourself to identify the various indicators on the generator equipment. Ask yourself what would be wrong if such and such an indication is observed and what measures would you take to correct the fault.

It helps to become familiar with wiring diagrams, such as in figure 9-37 and to learn the physical locations of the components. Doing so will enable you to find and to troubleshoot them faster in an emergency.

Station personnel must observe all electrical safety precautions. Every electrical circuit, including those as low as 35 volts, is a potential source of danger. Never work on an energized circuit except in an emergency. In such a case, insulate yourself from ground by covering any



K1 – RUN RELAY
OV – OVER VOLTAGE
RP – REVERSE POWER
UF – UNDER FREQUENCY (400 CYCLE ONLY)
OL – OVERLOAD
SC – SHORT CIRCUIT
OP – OIL PRESSURE
WT – WATER TEMPERATURE
FL – FUEL LEVEL
OS – OVERSPEED

26.251

Figure 9-37.—Practical wiring diagram of a representative safety control system for portable generator sets.

adjacent grounded metal with insulating material, such as dry wood, rubber mats, dry canvas, or serveral thicknesses of heavy dry paper. Also, provide enough lighting, cover metal tools with insulating rubber, and wear rubber gloves. Always station men at appropriate circuit breakers or switches so that the switchboard can be deenergized immediately and have available a man qualified to render first aid for electric shock.

TROUBLESHOOTING

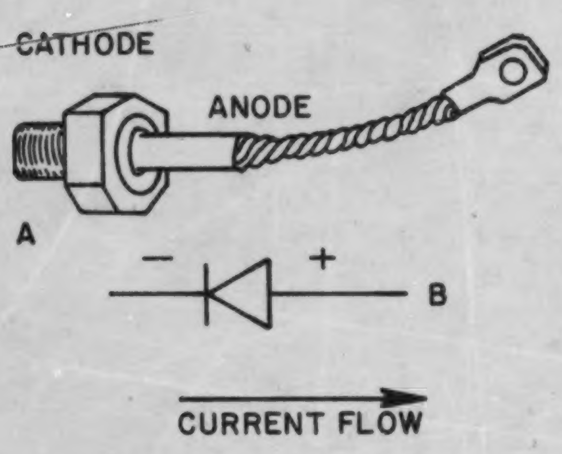
Component parts found in most SRCR controlled regulators are power rectifier, silicon controlled rectifier, full wave rectifier, saturable reactor, and choke.

The troubleshooting information that follows will enable you to check out each of these components. You will find the manufacturer's book the most reliable way to check out the entire system. Always check with the manufacturer's book when troubleshooting, ordering and replacing parts.

POWER RECTIFIER

A power rectifier (diodes) is used to change a-c to d-c. The power rectifier of figure 9-38 can be compared to a hydraulic check valve in that it only allows current to flow in one direction (the direction of the schematic arrow). Its characteristics are such that it has a high resistance in one direction and a low resistance in the other direction. Failures occur due to four reasons:

1. Excessive current - causes overheating.


CATHODE
ANODE
A
−
+
B
CURRENT FLOW

73,344
Figure 9-38.—Power rectifier.

2. Excessive voltage - electrically damages the rectifiers interior parts.

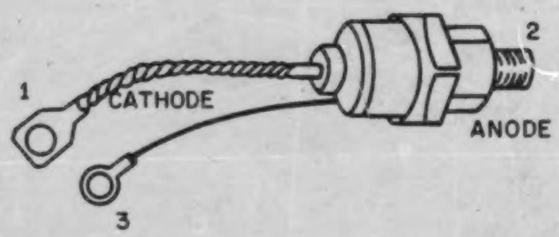
3. Too much torque when replacing diode—physically damages the rectifier's interior parts.

4. Lack of silicon lubricant—causes rectifier overheating due to no transfer of heat from the rectifier to the heat sink.

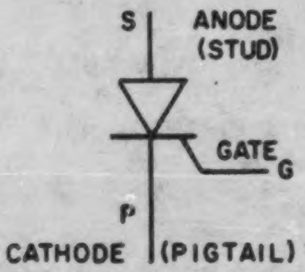
A power rectifier can be checked with an ohmmeter. Its resistance should be over 100 times higher in one direction than in the other (1,000 times higher on the silicon type).

Silicon Controlled Rectifier

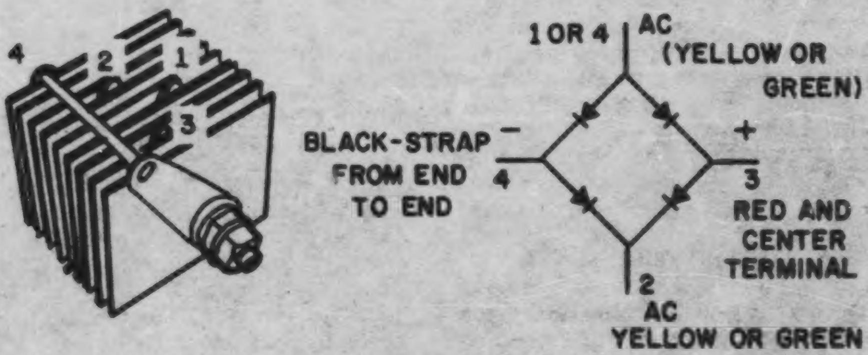
A silicon controlled rectifier (SCR) in figure 9-39, controls the amount of d-c that flows. It allows current to flow in one direction as a


1
CATHODE
2
ANODE
3

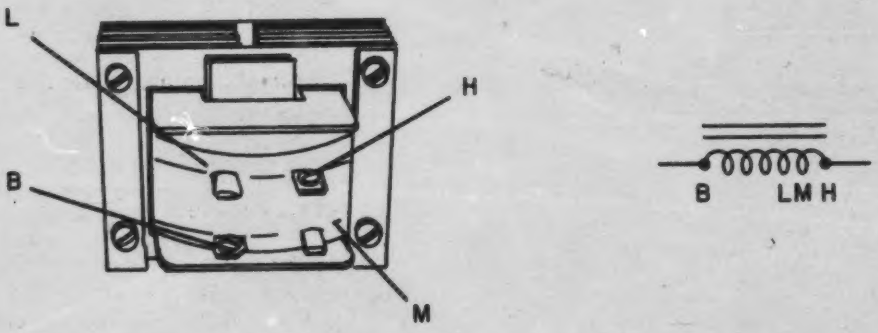
73,345
Figure 9-39.—Silicon controlled rectifier.


S
ANODE
(STUD)
GATE
G
P
CATHODE
(PIGTAIL)

73,346
Figure 9-40.—Cathode (pigtail).


4
2
1
3
1 OR 4
AC
(YELLOW OR
GREEN)
BLACK-STRAP
FROM END
TO END
−
4
+
3
RED AND
CENTER
TERMINAL
2
AC
YELLOW OR GREEN

73,347
Figure 9-41.—Full-wave rectifier.

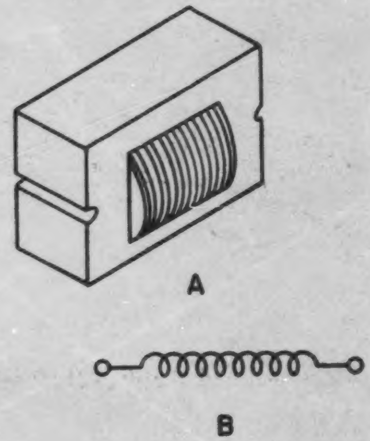


73.348

Figure 9-42.—Saturable reactor.

Table 9-4.—Rectifier check out

+1	-2	Reading high
	-3	Reading low
	-4	Reading high
+2	-1	Reading high
	-3	Reading low
	-4	Reading high
+3	-1	Reading high
	-2	Reading high
	-4	Reading high
+4	-1	Reading low
	-2	Reading low
	-3	Reading low



73.349

Figure 9-43.—Choke.

power rectifier does but only when a small positive voltage is applied to its gate terminal by some external means. When no positive voltage is applied to its gate terminal, the current will not flow through it.

A silicon controlled rectifier can be checked out with an ohmmeter. Readings across the terminals (fig. 9-40) should be as follows: terminals S-P, high ohms value; terminals S-G, high ohms value; and terminals P-G, 10 to 250 ohms.

Full-wave Rectifier

A full-wave rectifier (fig. 9-41) is used to change a-c to d-c. Consisting of four diodes arranged as shown in the figure, it fully rectifies a-c to d-c to allow full current flow; a single rectifier or diode allows only half of the a-c to flow.

It can be checked with an ohmmeter by placing the positive and negative ohmmeter leads as follows using table 9-4 as a guide: Place positive test lead on No. 1 terminal and negative test lead on No. 2 terminal. The reading should be high. Then place negative lead on No. 3 terminal, reading should be low, etc. If one of these readings is incorrect, the full-wave rectifier can be discarded.

Saturable Reactor

A saturable reactor (fig. 9-42) consists of a coil that is wound around an iron core. It enables a small change in voltage to produce a large change in current. The terminal B is one end of the coil and the other end is L-low, M-medium, or H-high, each corresponding to a different number of turns in the coil which affects the operating characteristics. A saturable reactor can be checked with an ohmmeter for continuity and grounds.

Choke

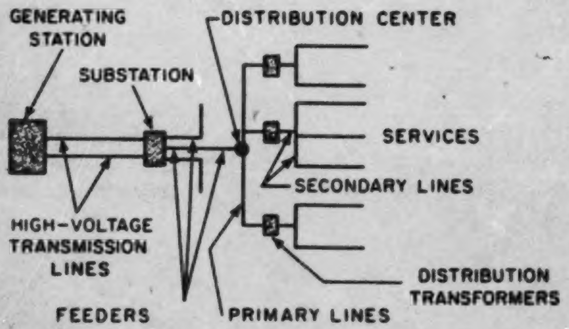
A choke (fig. 9-43) is used to smooth out a pulsating (rough) d-c. Like the saturable reactor, a choke is a coil of wire wound around an iron core. Its operating characteristics enable it to resist sharp changes in current flow. When placed in a circuit, the choke will smooth out any d-c flow. A choke can be checked with an ohmmeter for continuity and grounds.

CHAPTER 10

OVERHEAD POWER DISTRIBUTION

Power from the generating plant at an advanced base may be carried to the various points of consumption by overhead transmission and distribution lines, by underground cable, or by a combination of both. At most advanced bases, the high voltage developed at the central power station is usually, and preferably, distributed by overhead feeder lines. Such lines are cheaper to build, simpler to inspect, and easier to maintain than underground cables. Obviously, use of underground cables is preferred at airports to prevent hazardous flight conditions.

Voltages developed normally range from 120/208 volts to 7620/13200 volts. The initial generation and distribution system at an advanced base is provided by a 110/220 volt, 3-phase, 4-wire grounded neutral. Replacement may then be provided by a 2400/4160 volt, 3-phase, 4-wire grounded neutral supplied by banks of two or more generators. Finally, as requirements increase, power sources capable of providing the larger voltages are installed.



26.77

Figure 10-1.—Transmission and distribution system.

Whether underground or overhead, the distribution system at an advanced base is of the radial type. A representative transmission and distribution system is shown in figure 10-1.

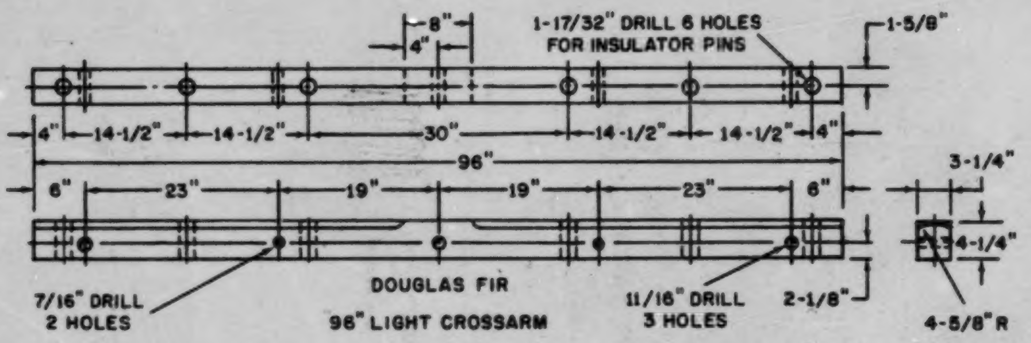
While working on a line crew you will be involved with the various stages of line work. You will begin as a groundman (helper), learning the proper procedures of doing line work, hardware required, special line tools used, and types of transformer hookups. Later on you will work as a lineman, mounting crossarms, stringing wire, and installing protective devices.

Your line crew leader will start off by explaining the project details from a set of blueprints. These details will include the route, class of poles, and type and size of transformers required for the project.

The basic concepts of pole line design are considered in the layout of each powerline job. Factors that are considered in designing the job are: the route, power load requirement, location and size of transformer banks, and class and types of poles suited for the project.

The line work generally accomplished by a battalion can be found in a standard set of drawings, Facilities Planning Guide, P-437, volume I (this replaces the P-140 series, Advance Base Drawings). This publication gives project layouts and lists materials needed to accomplish the project as shown.

This chapter provides information that will be useful to the CE engaged in the installation and maintenance of an overhead power distribution system. Topics covered include pole line components, powerline erection, distribution and current transformers, street lighting fixtures and circuits, and obstruction lighting. A section also is included on troubleshooting, along with a troubleshooter's chart for the series circuit.



73.351

Figure 10-2.—Crossarms.

POLE LINE COMPONENTS

The basic components in a power distribution system are: poles; crossarms that will go on the poles; insulators and insulator pins; transformers and protective devices. Information on each of these components is given in various sections of this chapter.

POLES

Three types of poles used in distribution systems are: wood, steel and concrete. You will run across all three types but will be working mostly with wooden poles.

Wooden poles are commonly classified as to length, top circumference, and circumference measured 6 feet from the butt end. The length varies in 5-foot steps and the circumference at the top varies in 2-inch steps. The circumference, measured 6 feet from the butt end, determines to which class (numbered from 1 to 10) a pole of a given length and top circumference belongs. The classification from 1 to 10 determines the strength to resist loads applied 2 feet from the top.

CROSSARMS

Crossarms are the crosspieces on a pole which support the insulators and conductors of a line. There are four widely used standard sizes of wooden crossarms; namely, 3 1/4'' by 4 1/2'', 3 1/2'' by 4 1/2'', 3 3/4'' by 4 3/4'', and 4'' by 5''. The first two of these sizes are standard for distribution work, and the latter two sizes are for transmission work. Crossarm length depends on the number of pins and the separation between pins. Standard crossarms include two-, four-, six- and eight- pin sizes with standard pin spacing of 30 inches between pole pins and 14 1/2 inches between outside pins as shown in figure 10-2.

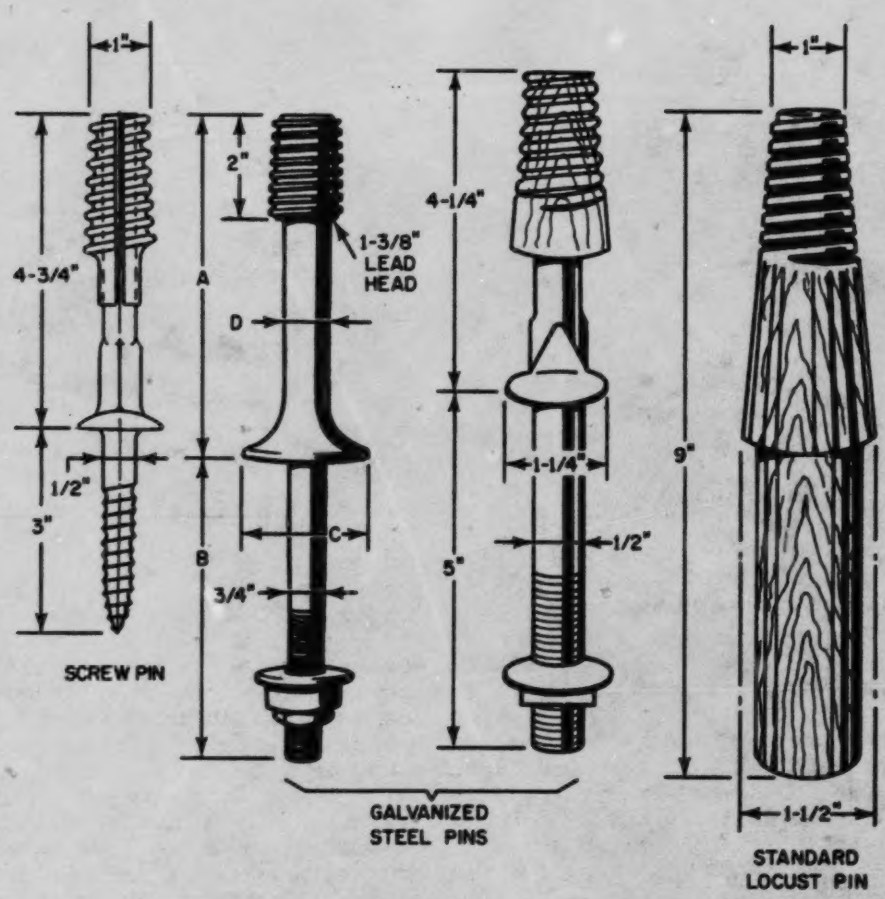
INSULATOR PINS

Insulator pins are used to mount the insulator on the crossarm. They may be either wood or steel (see fig. 10-3). For wood pins, well-seasoned locust in standard sizes for the arms and insulators is used. For galvanized steel pins, use the minimum lengths recommended by the insulator manufacturer. They are available in two sizes; long shank for use on wood arms and short shank for use on steel arms.

Standard-pin thread sizes are 1 inch and 1 3/8 inches. With insulators having porcelain threaded pinholes, use pins having lead thread. Use solid steel threads on pins only for insulators with metal thread pinholes.

INSULATORS

Insulators for overhead lines are classified into three classes: (1) pin, (2) suspension, and (3) strain (or clevis) type. The porcelain pin types illustrated in figure 10-4 are the most



73.352

Figure 10-3.—Insulator pins.

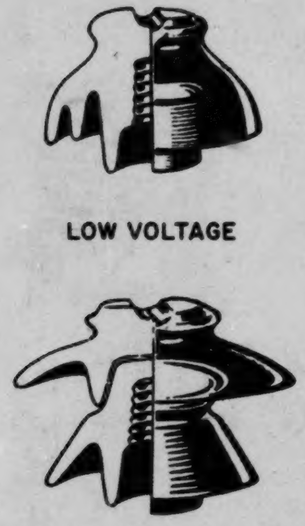
commonly used. The one-piece type is used for low voltage. The two-piece type (and larger size types) is used on high voltage lines. One-piece insulators are used for voltages below 23,000 volts; two-piece insulators for 23,000 to 44,000 volts; three-piece insulators for 44,000 to 66,000 volts; and four-piece insulators for 66,000 to 88,000 volts. The layers on these insulators are called petticoats or skirts. They help to spill rain and provide a long, dry arc-over path.

Suspension insulators (see fig. 10-5) were developed when voltages were increased above 44,000 volts. They are a big advantage since pin insulators become quite heavy at these high voltages and make it difficult to obtain sufficient mechanical strength in the pin to support the insulator.

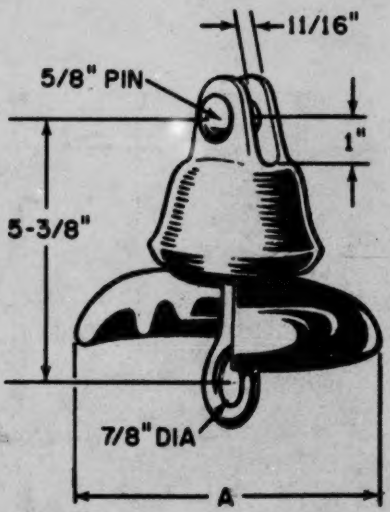
Strain (or clevis) type insulators are used on primary systems at corners, angles, dead ends, suspended buses, and wherever pins do not provide adequate support. They are built the same as suspension type insulators but are stronger mechanically.

HARDWARE

Hardware consists of a variety of bolts, nuts, screws, braces and clamps, which enable



73.353
Figure 10-4.—Pin type insulators.



73.354
Figure 10-5.—Suspension type insulator.

you to mount crossarms, string guy wires, and hang transformer banks. Figure 10-6 is an example of some of the common types of hardware with which you will be working.

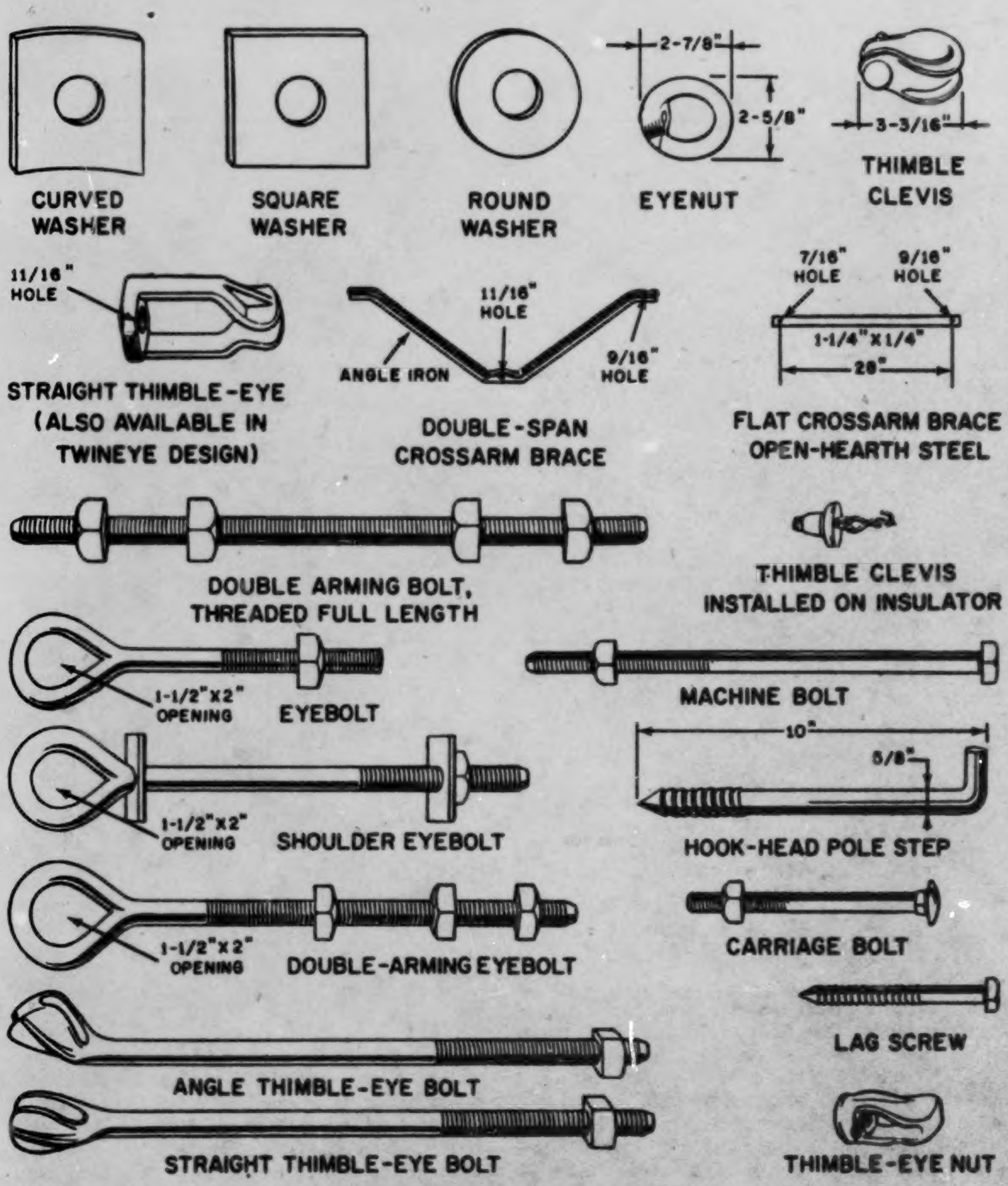
PROTECTIVE DEVICES

Circuit protective devices are divided into two main categories: primary devices and secondary devices. The primary devices protect the high-voltage transmission lines, the transformer installations, and the substations. The secondary devices protect the electrical equipment on the secondary side of the transformers—that is, the lighting circuits, motors, and other appliances which are the final consumers of power. In this chapter we are mainly concerned with primary devices. Information on secondary devices is presented in the chapter on interior wiring (chapter 8).

The primary protective devices consist of fused disconnect switches, circuit breakers, lightning arresters, and grounds.

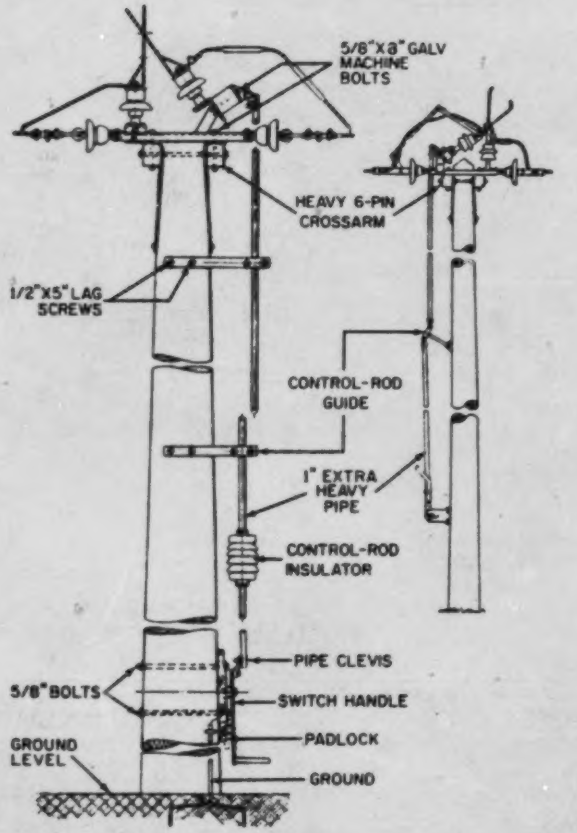
Disconnect switches used in transmission lines are not, strictly speaking, true protective devices, because they are used for isolating only certain parts of the line. By opening a disconnect switch, linemen can cut a line off from the main line or circuit, for repair work, without deenergizing the complete circuit. This type of switch is made for single-pole or gang operation. Although it may be motor-operated, it is more commonly operated by hand on the ground, by throwing a switch handle. Both handle and rod must be grounded. A handle-to-the-ground operated gang disconnect switch must also have some means of locking the switch in ON or OFF position, to prevent operation by an unauthorized person. Figure 10-7 shows gang-operated disconnect switches.

Primary cutouts or fused disconnect switches are placed ahead of tranformers, in the primary feeder, to open the circuit should the transformer become overloaded to a dangerous point. They are also used to isolate the transformer in order to make repairs or changes on the secondary line. Figure 10-8 shows a 100-ampere 7500-volt fuse disconnect equipped with a standard fuse holder and fuse link. By substituting the switch blade (shown at left of cutout) for the fuse holder, the cutout can be used as a straight disconnect switch. The switch blade has a 200-ampere carrying capacity. Figure 10-9 shows open-type fused disconnect switches. Disconnect


CURVED WASHER
SQUARE WASHER
ROUND WASHER
2-7/8"
2-5/8"
EYENUT
3-3/16"
THIMBLE CLEVIS
11/16" HOLE
STRAIGHT THIMBLE-EYE (ALSO AVAILABLE IN TWINEYE DESIGN)
11/16" HOLE
ANGLE IRON
9/16" HOLE
DOUBLE-SPAN CROSSARM BRACE
7/16" HOLE
9/16" HOLE
1-1/4" X 1/4"
28"
FLAT CROSSARM BRACE OPEN-HEARTH STEEL
DOUBLE ARMING BOLT, THREADED FULL LENGTH
THIMBLE CLEVIS INSTALLED ON INSULATOR
1-1/2" X 2" OPENING
EYEBOLT
MACHINE BOLT
10"
5/8"
1-1/2" X 2" OPENING
SHOULDER EYEBOLT
HOOK-HEAD POLE STEP
1-1/2" X 2" OPENING
DOUBLE-ARMING EYEBOLT
CARRIAGE BOLT
LAG SCREW
ANGLE THIMBLE-EYE BOLT
STRAIGHT THIMBLE-EYE BOLT
THIMBLE-EYE NUT

73.355

Figure 10-6.—Pole line hardware.

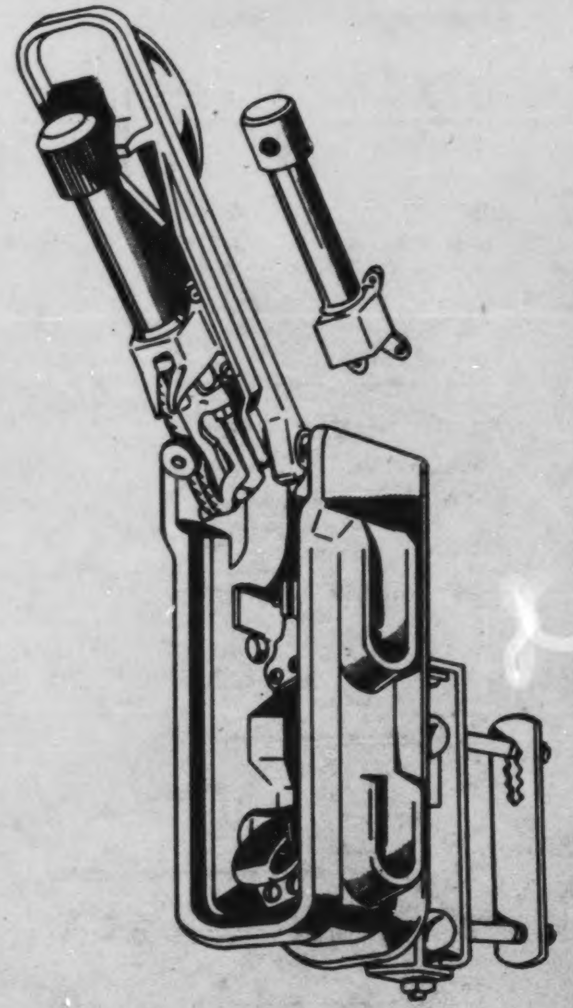

5/8"X8"GALV MACHINE BOLTS
HEAVY 6-PIN CROSSARM
1/2"X5" LAG SCREWS
CONTROL-ROD GUIDE
1" EXTRA HEAVY PIPE
CONTROL-ROD INSULATOR
PIPE CLEVIS
5/8" BOLTS
SWITCH HANDLE
PADLOCK
GROUND LEVEL
GROUND

73.356
Figure 10-7.—Gang-operated disconnect switches.

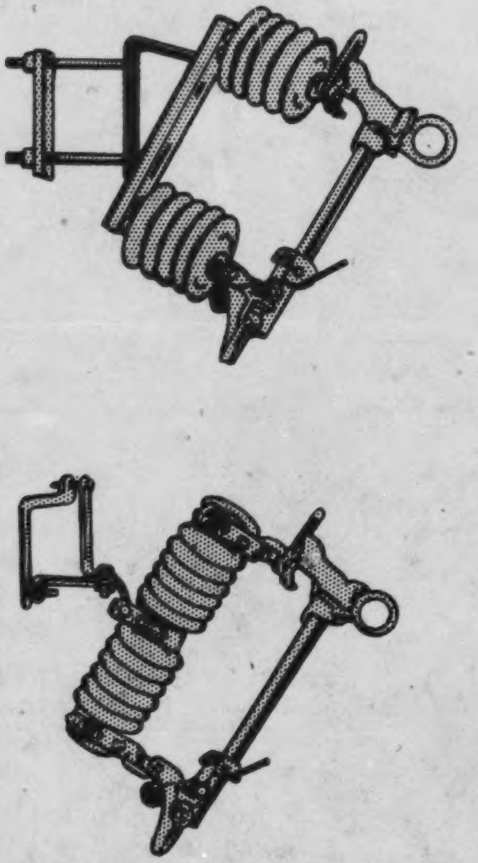
switches are generally used in the primary circuit when opening the circuit is necessary under voltage but with little or no load current.

Oil circuit breakers are used in circuits carrying more than 600 volts. One of these can be used to open a circuit automatically upon overload. They are generally designed and connected for one or more automatic reclosings, thus restoring service rapidly when a fault has cleared itself. Oil switches are, therefore, used where control of a high-current circuit as well as protection from overload and short circuit are desired.

Some transformers are protected against excessive voltages and overload by lightning arresters and circuit breakers which are integral parts of the transformer (fig. 10-10). A heavy overload on the secondary circuit opens a breaker inside the tank, disconnecting the transformer from the load. Overloads not large enough to damage the transformer cause an indicating light on the outside of the tank to turn on. The glowing light indicates that the load is too large. Unless the overload is only temporary, the transformer must be replaced by one of larger capacity.



73.101
Figure 10-8.—Fused cutout and disconnect blade.

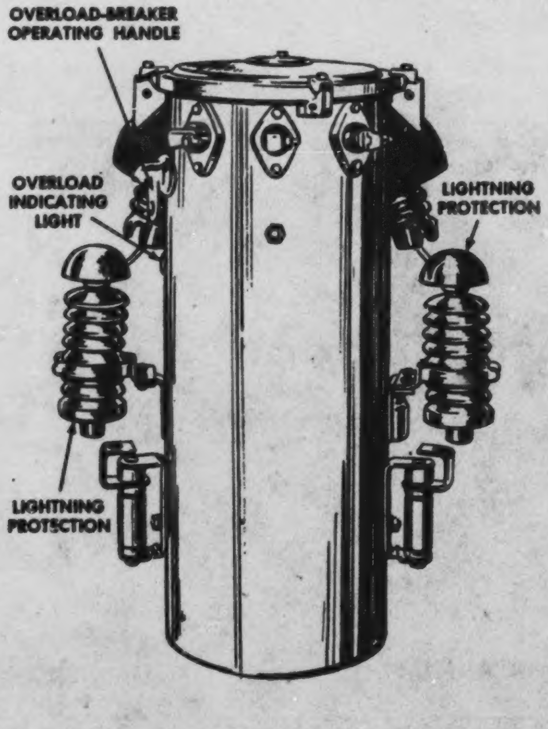


73.102
Figure 10-9.—Open-type fused disconnect switches.

or some of the load must be transferred to a different transformer.

LIGHTNING ARRESTERS

Various types of lightning arresters are used in transmission work. A few examples of lightning arresters which you may encounter in your work are shown in figure 10-11. A lightning arrester protects a line against the very high voltage which occurs when lightning strikes. When a voltage rise above normal occurs, an arch forms across a horn-gap in the arrester and the overload passes from the horn-gap to ground through the ground wire or other grounding device. This is the same action as a safety valve on a steam boiler. When an excess of pressure builds up in the boiler, the valve relieves the excess by opening up. It then closes automatically as the pressure returns to normal.



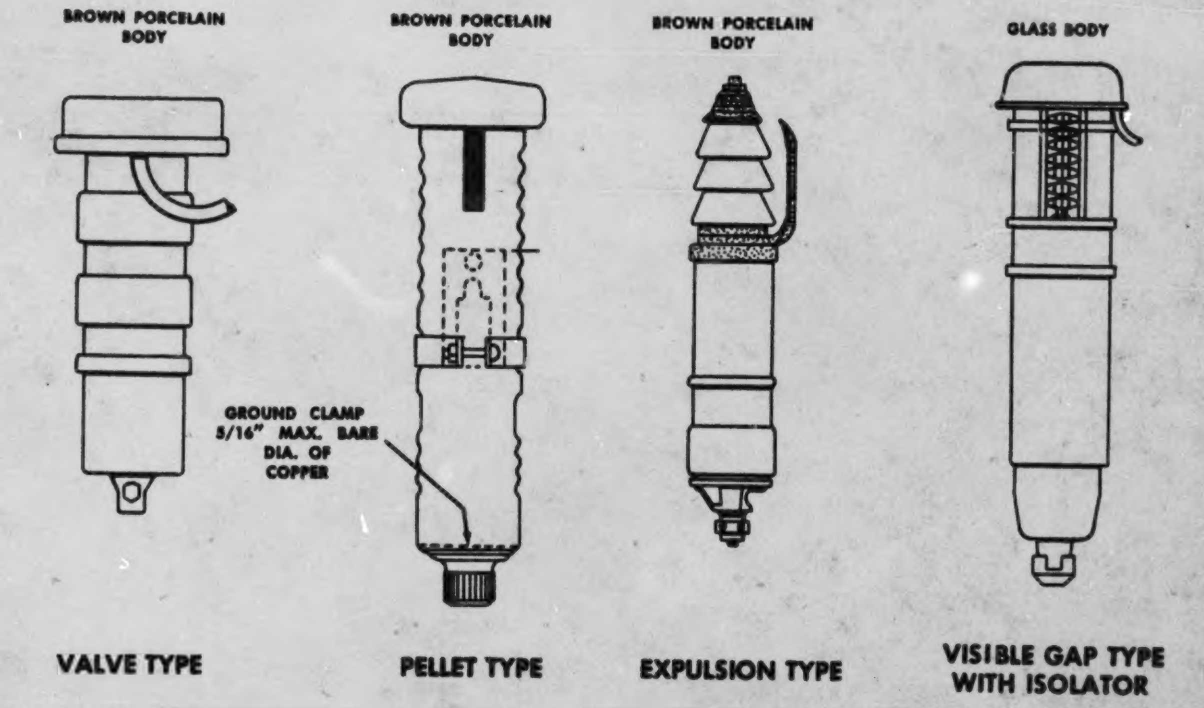
73.103
Figure 10-10.—Self-protected transformer.

POWERLINE ERECTION

The erection of powerlines is a responsibility of the CE 3 and 2. This phase of our discussion will acquaint you with various duties involved in the erection of powerlines; for instance, preparing poles, erecting the poles, stringing and tying conductors, and so on. We will also cover safety apparel and equipment, care of pole-climbing equipment, and safety precautions to be observed in the erection of powerlines.

PREPARING POLES

At an advanced base you may have to use standing trees as poles. If this is so, select the straightest trees you can find and trim them.



73.104

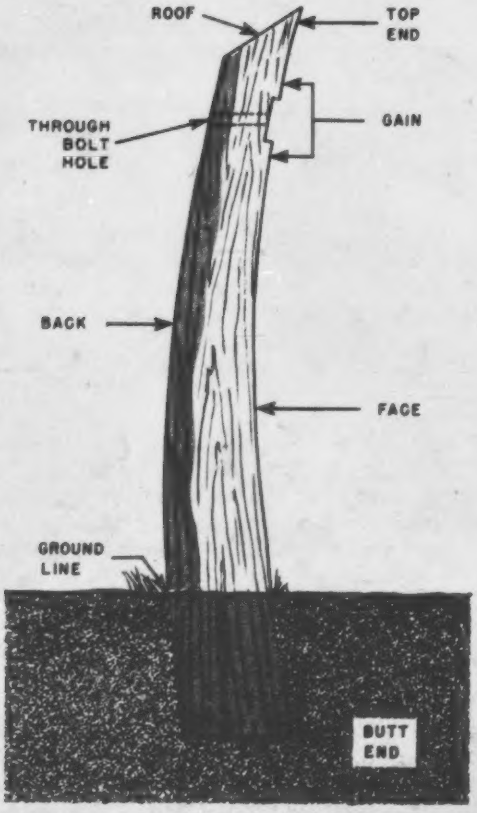
Figure 10-11.—Types of lightning arresters.

Trimming consists of cutting branches off flush with the trunk. This procedure is necessary to make the pole safe for a lineman to climb using tree gaffs.

Most of the poles you will use will be already trimmed and treated with creosote (to prevent rotting) before they arrive at the site. Creosote is a toxic compound that will blister the skin. Therefore, use gloves when handling or climbing creosote-treated poles and AVOID touching your eyes with the gloves. Be sure to have your sleeves rolled down.

The next step is to cut the "roof" (a roof-like cut at the upper end, made by sawing a single slant cut that drains toward the back of the pole) and the "gains" (a gain is a notch in which a crossarm is set). This cutting should be done with the pole in a rack of some kind which will hold one end of the pole above the ground. If the pole is curved, it should be set in the rack so that the curve or sag is toward the ground. Then cut the roof diagonally and the gain or gains on the upper surface, so that the relation of roof to gains is as shown in figure 10-12. Remember that the gain is always cut on the face of the pole, and the face is the inside of any curve the pole may have. Following this rule ensures that the pull of wires on the crossarm will be against the curve of the pole. Remember, too, that the slope of the roof should be parallel to the wire lines, not across them. The reason for this is to ensure that water draining off the roof will run down the back of the pole, and not into the crossarm gains.

The center of the first or top gain should be located 12 in. from the top of the pole. Since the width of the gain is the height of the crossarm, measuring half the height of the crossarm above and below the center of the gain will give you the top and bottom of the gain. The gain should be cut about 1/2 in. deep. It is good practice to make the gain slightly concave, so the crossarm will bear solidly against the outer ends.


ROOF
TOP END
THROUGH BOLT HOLE
GAIN
BACK
FACE
GROUND LINE
BUTT END

29.233

Figure 10-12.—The parts of the pole.

The spacing between succeeding gains depends on the voltage in the lines. For voltages up to 8700 volts the minimum spacing is 24 in. For voltages from 8700 volts to 50,000 volts the minimum spacing is 48 in.

The next step is to bore the hole for the crossarm through-bolt in the center of the gain (see fig. 10-12). The standard through-bolt has a diameter of 5/8 in. The diameter of the bolt hole should be 11/16 in. To center the hole, draw intersecting diagonal lines across the gain.

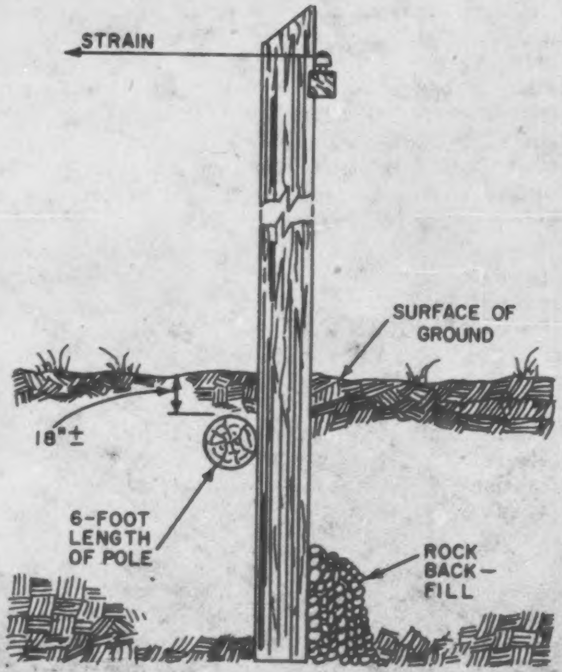
DIGGING POST HOLES

The depth for a pole hole depends on the length of the pole and the composition of the soil. A hole in firm, rocky terrain does not need to be as deep as a hole in soft soil. Table 10-1

Table 10-1.—Depth for setting pole in soil or rock

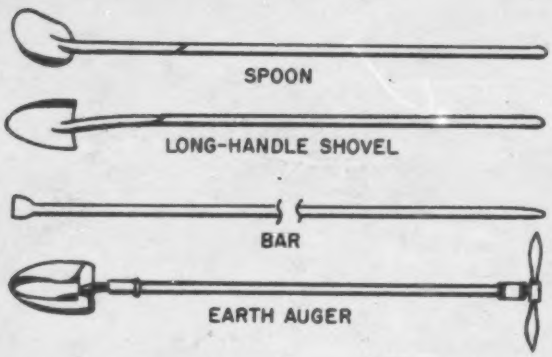
Length of pole (ft)	Setting depth (ft) In soil	Setting depth (ft) In rock
20	5.0	3.0
25	5.5	3.5
30	5.5	4.0
35	6.0	4.0
40	6.0	4.0
45	6.5	4.5
50	7.0	4.5
55	7.5	5.0
60	8.0	5.0

73.310


STRAIN
SURFACE OF GROUND
18"±
6-FOOT LENGTH OF POLE
ROCK BACK-FILL

73.69

Figure 10-13.—Cribbing a pole with stone and log.

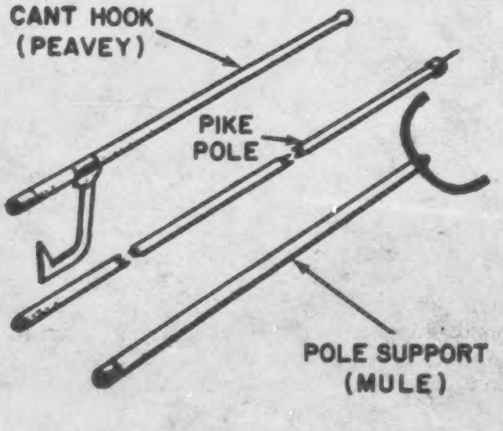


29.234

Figure 10-14.—Digging tools.

gives recommended post-hole depths for poles from 20 to 60 ft long in firm soil and in rock.

A pole set in sandy or swampy soil must be supported by guys or braces, or by "cribbing." Cribbing means the placement of some firm material around the part of the pole that is below ground. One method of cribbing is to sink an open-bottom barrel in the hole, set up the pole in the barrel, and then fill the space around the base of the pole with concrete or small stones after the pole has been plumbed (brought to the vertical). Another method of cribbing is shown in figure 10-13.



29.235

Figure 10-15.—Pole tools.

There may be a power-driven hole-digger available, but in the absence of one of these the holes must be dug by handtools (fig. 10-14). You use a "digging bar" to loosen the soil. About the first 2 ft of depth can be removed with a short-handle shovel. Below that you loosen the earth with an earth auger or long-handle shovel, and haul it up with a long-handle device called a spoon.

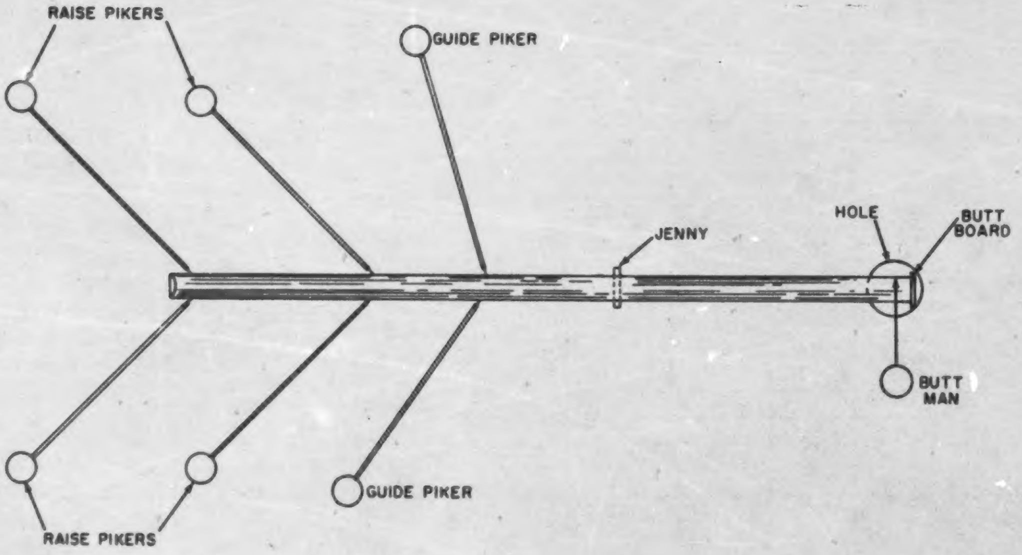
A hole should have a diameter about 6 in. larger than that of the base of the pole, to allow room for tamping backfill. It should be a little larger at the bottom, to allow for plumbing the pole.

ERECTING POLES

If a line truck with winch and A-frame is available, the job of erecting poles is simple. A sling is placed around the approximate midpoint of the pole and the winch heaves it up. The truck then proceeds to the hole, and the base of the pole is guided in as the winch lowers away. Since the butt or base is heavier than the top end, the pole will be raised to an almost vertical position.

In the absence of this equipment, the pole must be "piked up"—meaning that the pole is placed with base adjacent to the hole and the upper end supported on either a "mule" or a "jenny." A jenny is a wooden support made in the form of an X, while a mule is a wooden support made in the form of a Y. The upper end is then "piked" into the air by men using pike poles. A pike pole and mule are illustrated in figure 10-15.

This procedure is illustrated in figure 10-16. The "butt man" holds and guides the butt of the pole with a cant hook or "peavey" (see fig. 10-15). This is a handle, the hook being designed to grasp the pole when pressure is applied to the handle. As the upper end of the pole is raised, a man keeps the jenny or mule in approximate contact by moving it toward the butt. The "butt board" is a length of plank, set in the hole and long enough to protrude above the surface. It prevents the butt of the pole from sliding past the hole, and also prevents the butt from caving in the side of the hole. After the pole



73.70

Figure 10-16.—Piking up a pole.

has reached upright position, it is "faced"—meaning that it is rotated with the cant hook to bring the crossarm gain to proper position. On a straight line it is the custom to set adjacent poles with crossarms facing in opposite directions, as shown in figure 10-17. This procedure, called facing "gain to gain" or "back to back," provides for maximum strength in the line.

On a curve the gains must be set so that the crossarm is on the side of the pole nearest the center of the curve, as shown in figure 10-18.

After the pole has been faced, it must be plumbed vertical. This is done by four pikers on four sides of the pole, acting on signals given by one man who sights along the line and another who sights from one side. In some cases a small amount of rake or lean (approximately 12 inches) is left to allow for a wire strain or the normal give of a guy.

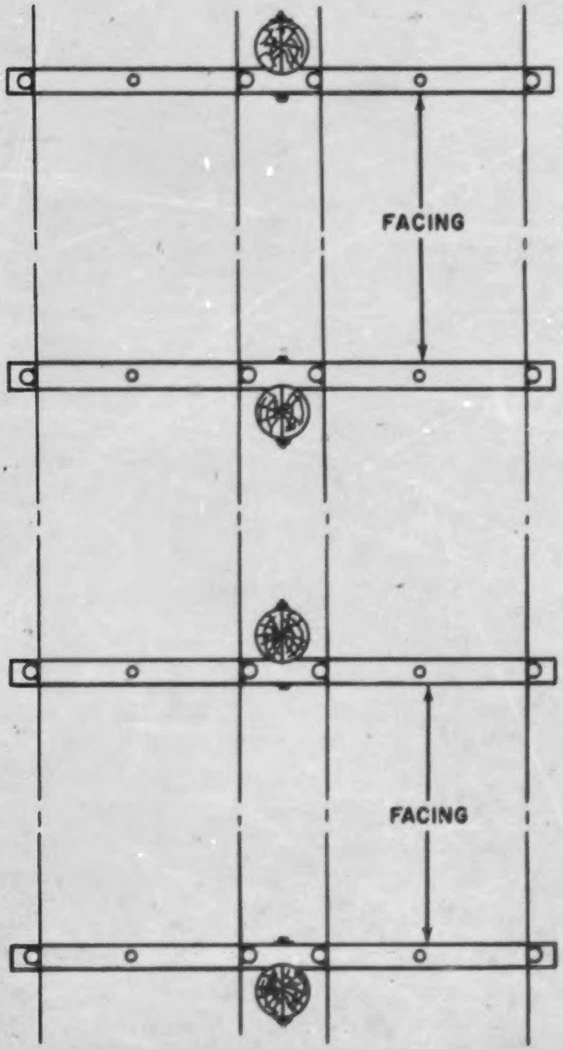
After the pole has been plumbed, the hole is backfilled and the backfill tamped down hard. Backfilling should be done gradually, in shallow layers, with each layer thoroughly tamped down. Usually two or three men tamp while a single man shovels. When the hole has been filled to the ground line with tamped backfill, the remaining excavated soil is banked in a mound around the base of the pole, to allow for subsequent settling.

SAFETY IN POLE RAISING

As a pole is being raised, it is safest to assume that at any moment something may slip or break. Stand as far away from the pole as possible if you are not in the raising crew.

The pike-pole method of setting poles should not be used unless there are enough men to do the work safely. In using pikes, the men must stand far enough apart so that they will not interfere with each other. Never brace a pike pole on your stomach. If the pole shifted your way, you would not be able to get clear. Unmanned pikes alone should not be relied upon to support a pole while a man is on it. All pike pole tops should be kept covered at all times except when actually in use.

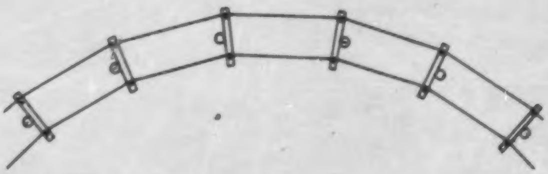
Workmen should not be on poles while they are being plumbed, canted or tamped.



73.71

Figure 10-17.—Facing crossarms on a straight line.

A "guy" is a brace or cable which is "anchored" in some fashion at the lower end, and secured to a point on the pole at the other, and serves to brace the pole in position. Normally, cable or wire guy is made of 7-strand galvanized steel. There are various types of guys used, some of which are as follows:



73.72

Figure 10-18.—Facing crossarms on a curve.

A "line" guy is one installed in a straight pole line and parallel to the line, to reinforce the line against stress caused by broken conductors.

A "head" guy is one which runs from the top of one pole to a point below the top on another pole.

An 'arm" guy is one which runs from the end of a crossarm to the next adjacent pole. It is used when a line dead ends at the end of a crossarm.

A "storm" guy (fig. 10-19) is one installed in a line to prevent the entire line from being pulled down in the event that line conductors should break at some point in the line. A storm guy consists of two line guys (that is, guys running parallel to the line) and two side guys (guys running crosswise to the line). Storm guys are usually installed at intervals of 1/2 mi to 1 mi.

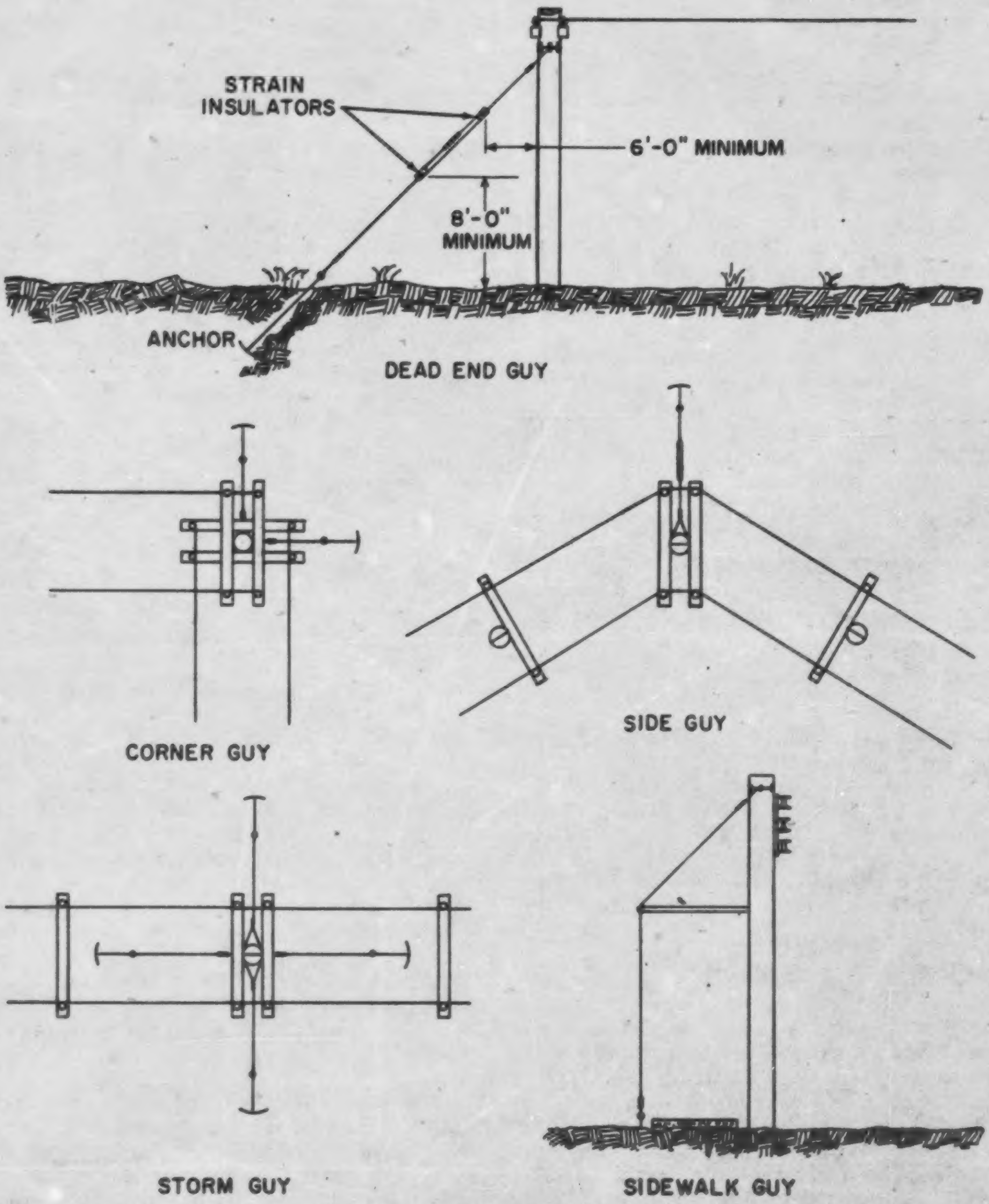
A "sidewalk" guy is outrigged (as shown in fig. 10-19), so the guy will not obstruct pedestrain traffic on the sidewalk.

A guy which runs from the top of a pole to a ground anchor is called a "down" guy.

A "stub" guy runs from the top of a pole to the top of a shorter pole called a stub. The stub is itself braced by a down guy.

Locating Guys

Guys are installed at any place in the line where the stress of the conductors could pull the crossarms or the pole out of proper position. It is not possible to mention all the situations which call for guying, but some important guy locations are as follows:


STRAIN
INSULATORS
6'-0" MINIMUM
8'-0"
MINIMUM
ANCHOR
DEAD END GUY
CORNER GUY
SIDE GUY
STORM GUY
SIDEWALK GUY

73.73

Figure 10-19.—Types of guys.

DEAD ENDS.—Dead ends or terminals must be guyed as shown in figure 10-19.

CORNERS.—Corners (that is, poles where the line changes direction radically) must be guyed as shown in figure 10-19.

BRANCHES.—Where a branch line takes off from a main line, a side guy (fig. 10-19) should be installed to support the stress of the branch line.

ANGLES.—A corner is, of course, an angle, but it is an angle which comes close to 90°. When a line makes ANY angle, however slight, a side guy should be installed. For a large angle, two or more guys should be installed.

CROSSINGS.— Electric lines crossing railway tracks must be equipped with head guys installed on poles on both sides of the crossing. These guys run from the top of the pole adjacent to the tracks to about midway of the next pole.

Strain Insulators

All guys on powerlines should have one, preferably two, strain insulators installed in the guy to break contact between the upper part of the guy and the part low enough to be contacted by persons on the ground. The lower insulator should be at least 8 ft above the ground and the upper one should be placed at least 6 ft from the pole to prevent electrical contact (fig. 10-19).

GUY ANCHORS

For securing the lower or ground ends of guys there are various types of "anchors" used, some of which are illustrated in figure 10-20. The "Never Creep" anchor (this is a trade name) is installed by digging a hole about 8 in. in diameter, at about a 45° angle and sloping down toward the pole. After the hole is dug, a rod is driven in the ground in line with the guy wire from the top of the pole. This rod intersects the hole at a right angle about 6 ft from the surface. The plate part of the anchor is then placed over the rod and locked on by the slot plate. A Never Creep anchor is shown in view A of figure 10-20.

The "expanding anchor" (view B of fig. 10-20) is installed by digging an 8-in. hole in line with the guy wire from the pole or at about a 45° angle. The anchor is put in the hole, and a heavy tamper is slipped over the rod. The anchor is rammed with the tamper until it expands to its full width. This usually takes about five or six blows with the tamper.

The "log" anchor (view C of fig. 10-20) is a simple do-it-yourself type which is very effective in soft or sandy soil. The log usually consists of a 6-ft long section of a pole. The trench is dug at right angles to the line of the guy, to a depth of at least 6 ft, and long enough to receive the log. A narrow trench, to accommodate the guy, is dug as shown. A threaded rod is run through a hole in the log and secured with nut and washer. The rod is long enough to permit the eye in the upper end to reach a point 6 in. above the ground line.

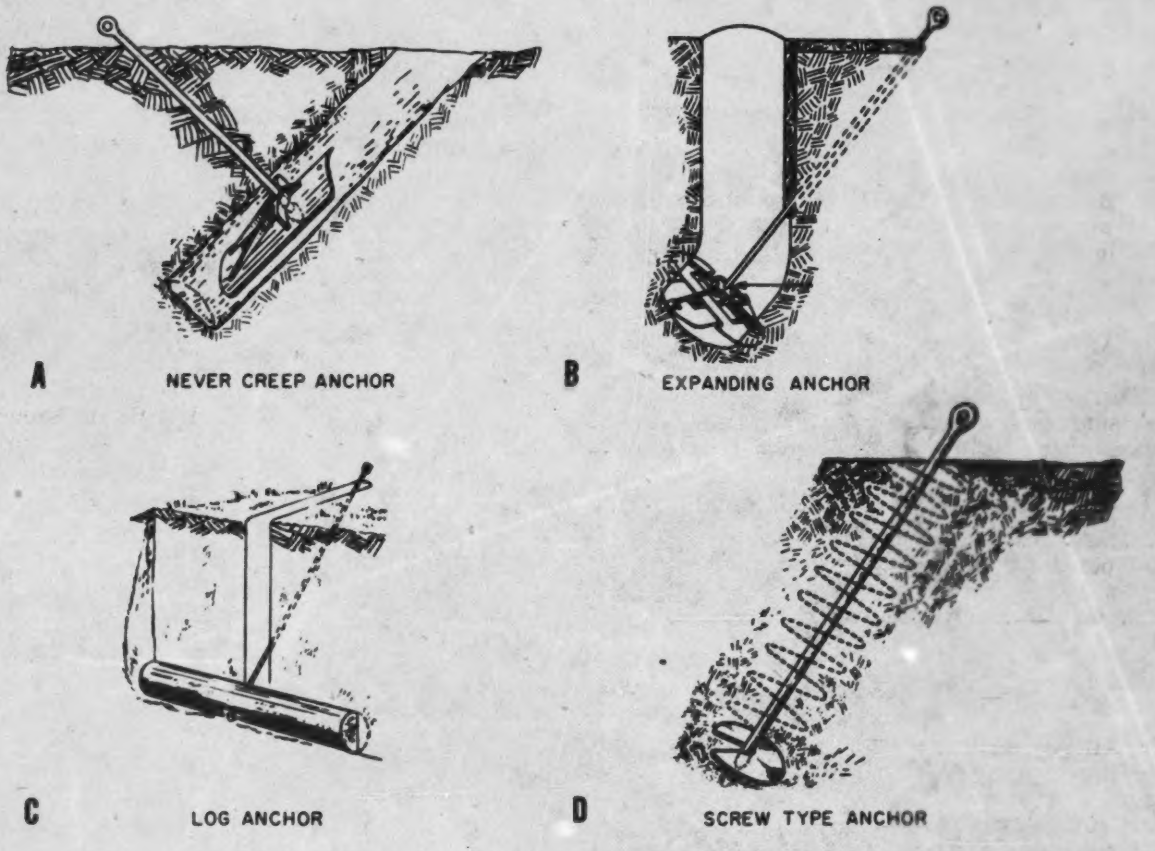
A "screw" type anchor is one which can be "screwed" into the ground as shown in view D of figure 10-20. A shallow hole is dug to start the screw blade, and the rod is then rotated by two men using a bar-toggle run through the eye.

CLIMBING POLES

To climb a wooden pole or tree you will use the equipment shown in the lower part of figure 10-21. The "stirrup" fits under the arch of your foot, and the leg iron runs up the inner side of the calf of your leg. This puts the "gaff" in a position on the inner side of your foot where you can drive it into the pole or tree as you climb. Two leather straps run through the loop straps and hold the climber tightly against your calf and ankle. The "leather" pad keeps the upper end of the climber from digging into your leg.

The term "leather" refers not only to treated animal hides but also to neoprene impregnated nylon products such as body belts, safety straps, and leg straps. These non-leather items are cleaned with soap and water and are available to the battalions.

The "safety strap" and "body belt" shown in the upper part of figure 10-21 are what might be called your extra pair of hands when you work aloft. The body belt, strapped around your waist, contains various pockets for small tools. The



73.74

Figure 10-20.—Types of guy anchors in general use.

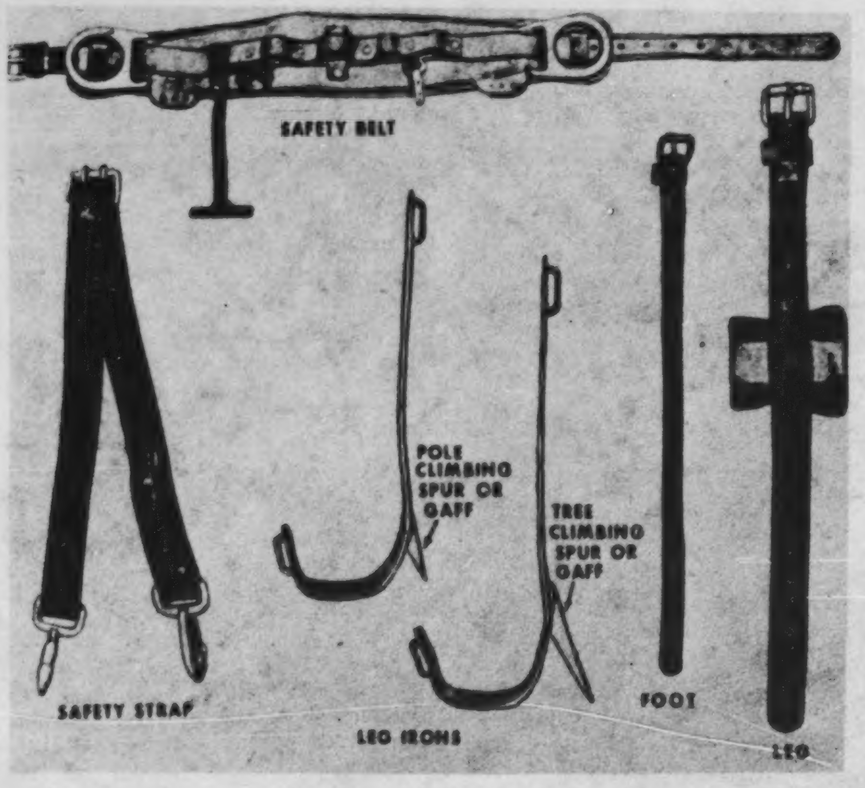
safety strap is a "leather" belt with a tongue-type buckle (keeper snap) at each end. While you are climbing you will have the safety strap hanging by both ends from the left ring (called a D-ring because of its shape) on the body belt. When you are at working position, you will unsnap one end of the safety strap, pass it around the pole, and hook it to the right "D" ring on the body belt. One adjustable buckle permits variation to suit the lineman and the circumference of the pole. You can now lean back against the safety strap and maintain a steady, comfortable, and SAFE position.

Care of Climbing Equipment

To a lineman the term "burning" a pole means the highly unpleasant experience of sliding all the way, or a good part of the way, down a pole as a result of defective equipment or some error in climbing technique made on the way up. The burning you get doesn't need to be explained in detail, and besides burning you may get a good many splinters. However, climbers, body belt, and safety strap should keep you up where you belong—if you use them properly and take proper care of them.

The body belt and safety strap require continuous inspection. Look for:

1. Loose or broken rivets.
2. Cracks, cuts, nicks, or tears in leather.
3. Broken or otherwise defective buckles.
4. Deffects in safety-belt snap hooks and body-belt D-rings.



73.357

Figure 10-21.—Pole-climbing equipment.

5. Worn leather.
6. Enlarged tongue holes for belt buckles.

If you discover any of these defects, turn in the equipment and replace it.

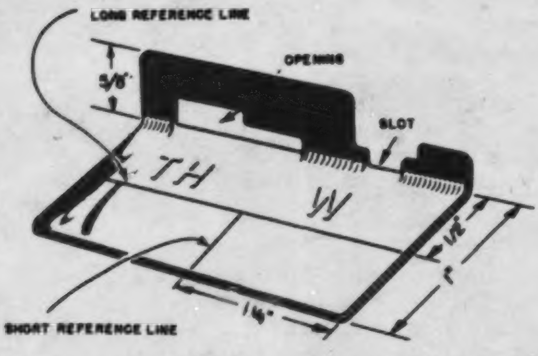
You must periodically perform maintenance work on the leather parts of your climbing equipment. Cleaning comes first. Use a damp sponge and a mild soap. Work up a thick, creamy lather. Then wash the soap off and wipe the belt with a dry cloth.

Next, to make the genuine leather soft and pliable, lather well with saddle soap. Work the lather into all parts; then place the belt in the shade to dry. After the lather has nearly dried, rub down the leather with a soft cloth.

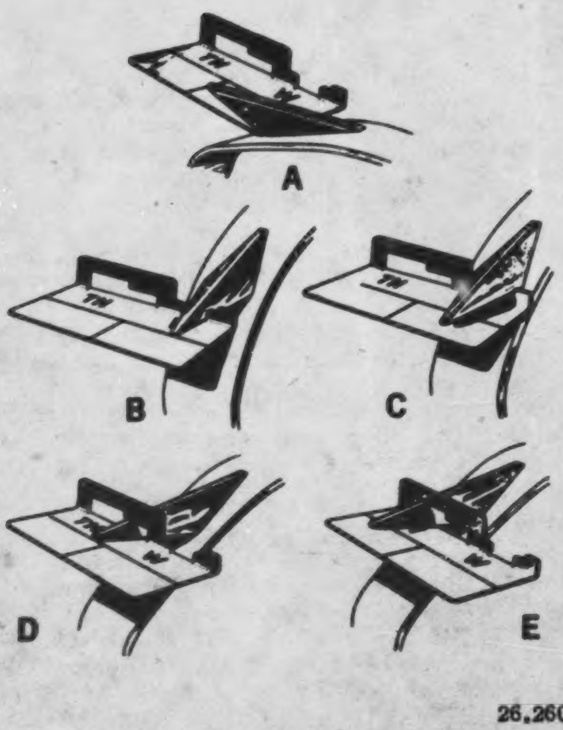
Body belts and safety straps made of genuine leather require oiling about every 6 months. Be sure the leather is clean before applying oil. Use about 2 teaspoonfuls of neat's-foot oil, working the oil in gradually. Place the belt in a shady place and allow to dry for 24 hours. Then rub down with a soft cloth.

Always, before you climb a pole or tree, inspect the climbers for the following defects:

1. Broken or loose straps.
2. Stirrup worn to a thickness of 1/8 in. or less.
3. Length of pole gaff or less than 1 1/4 in. as measured along the inner surface.
4. Length of tree gaff not less than 5 1/2 in. as measured along the outer surface and not less than 3 1/2 in. along the inner surface.
5. Difference in gaff lengths of more than 1/8 in.



26.259
Figure 10-22.—Climber's gage.



26.260
Figure 10-23.—Use of climber's gage.

If you find any of these defects, turn in your climbers for a new pair.

Climber's Gage

To minimize certain dangers which can occur from neglect of the climbers, make sure you check your gaffs frequently using a climber's gage (fig. 10-22). This gage is used to check the dimensions of gaffs. These must be within certain tolerances or the climber will "cut out" or lose contact with a pole or tree.

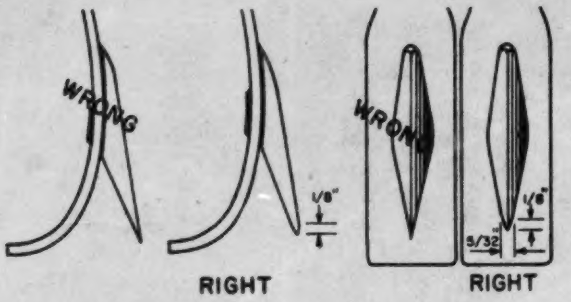
Measurements of the length, width, and thickness of the gaffs are made as follows.

LENGTH. Place the lined face of the gage against the inner surface of the gaff with the short edge of the gage held tightly against the crotch (fig. 10-23A). The crotch is the point where the gaff joins the leg iron. If the point of the gaff extends to or beyond the short reference line, the length of the gaff is satisfactory.

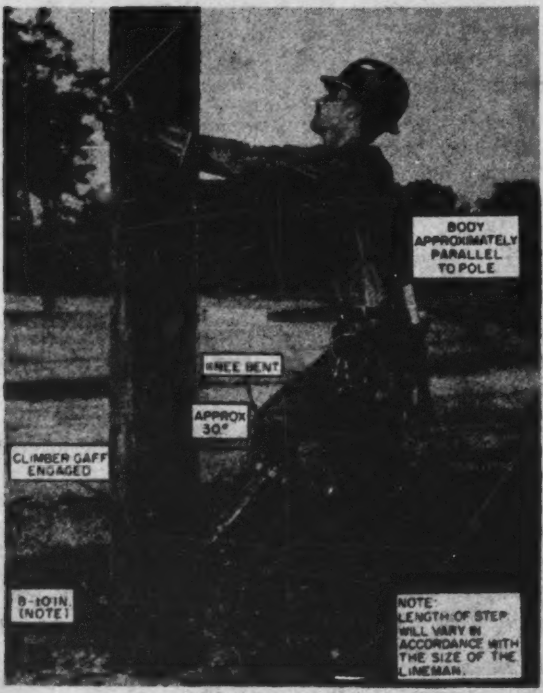
WIDTH. Insert the gaff as far as possible through the small slot marked W, with the inner surface of the gaff resting against the lined face of the gage (fig. 10-23B). If the point of the gaff does not extend beyond the long reference line, the width of this section of the gaff is satisfactory. Insert the gaff as far as possible through the large slot marked W, with the inner surface of the gaff toward the lined face of the gage (fig. 10-23C). If the point of the gaff does not extend beyond the far edge of the gage, the width of this section of the gaff is satisfactory.

THICKNESS. Insert the gaff as far as possible through the small opening marked TH, with the inner surface of the gaff resting against the lined face of the gage (fig. 10-23D). If the point of the gaff does not extend beyond the reference line, the thickness of this section of the gaff is satisfactory. Insert the gaff as far as possible through the large opening marked TH, with the inner surface of the gaff resting against the lined face of the gage (fig. 10-23E). If the point of the gaff does not extend beyond the far edge of the gage, the thickness of this section of the gaff is satisfactory.

Sharpen any dull gaffs by taking long strokes with a file from the heel to the point of the gaff, removing only enough material to make a good point. NEVER USE A GRINDSTONE OR EMERY WHEEL TO SHARPEN GAFFS, since the metal may become overheated and lose its strength



26.261
Figure 10-24.—Sharpening the gaffs.


BODY APPROXIMATELY PARALLEL TO POLE
KNEE BENT
APPROX 30°
CLIMBER GAFF ENGAGED
8-10 IN. (NOTE)
NOTE: LENGTH OF STEP WILL VARY IN ACCORDANCE WITH THE SIZE OF THE LINEMAN.

73.311
Figure 10-25.—Starting to climb a pole.

(temper). Never sharpen the gaff to a needlepoint (fig. 10-24) since it will sink too deep into the pole and make climbing difficult. Always leave a shoulder about 1/8 in. back from the point.

Remember that climbers are for use on poles ONLY. Do not wear them while working on the ground, and do not use the gaffs for such irregular procedures as the opening of cans and the like.

Going Up

Before starting to climb a pole, there are a number of preliminary steps that should be taken. First, of course, make the preclimb inspection of equipment previously described AND PUT ON YOUR HARD HAT. Then inspect the pole to determine the best side on which to start. This is usually the back, or high side.

Get against the pole and grasp each side of it with your hands—not that you will hand-support your weight in climbing, but simply because you will use your hands to help in balancing yourself on the climbers (fig. 10-25).

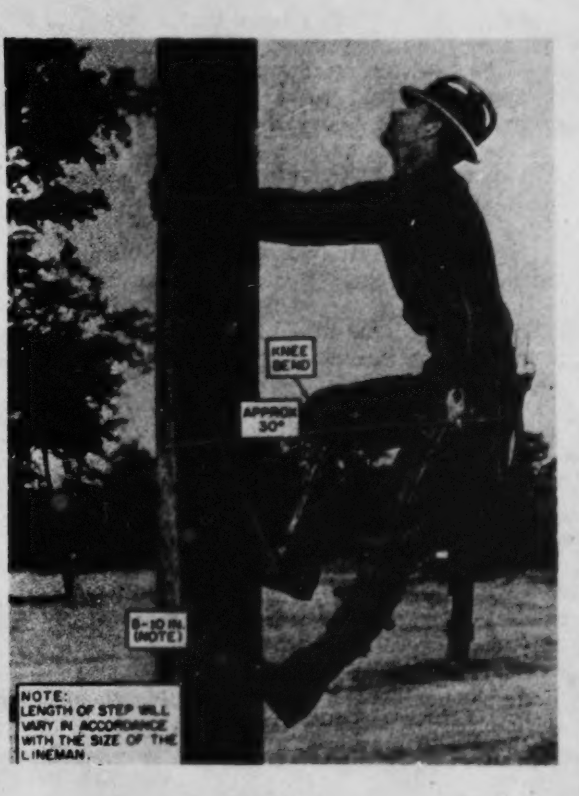
To learn pole climbing you must practice actual pole climbing. Some pointers that will help you become efficient in pole climbing in minimum time are as follows:

Raise your right leg about 8 in. off the ground and sink the gaff on that leg into the pole. Don't jab the gaff in the wood. Allow your weight to sink it in. Now, swing yourself up off the ground and lock your right leg in stiff-leg position, so that all your weight is supported on that leg.

As the next step, raise your left foot about 8 in. and sink the gaff on that foot into the wood. Then swing up onto the left leg stiff-legged, and take the next step similarly with the right foot. Continue this stepping up and locking stiff-legged until you reach working position. Keep the upper part of your body away from the pole; if you "hug" the pole, you will tend to throw the gaffs out of the wood (fig. 10-26).

At Working Position

At working position your feet should be placed so that most of your weight is on the right foot, stiff-legged. The left foot should be slightly above the right, so that the left leg is slightly bent. When you have attained this position, you must proceed immediately, with great care, to attach the safety strap.

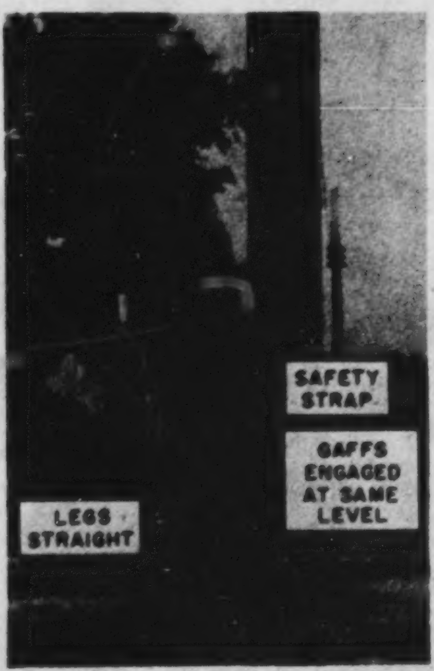

KNEE BEND
APPROX 30°
8-10 IN. (NOTE)
NOTE: LENGTH OF STEP WILL VARY IN ACCORDANCE WITH THE SIZE OF THE LINEMAN.

73.312
Figure 10-26.—Continuing the climb.

Crook your right arm around the pole. Use your left hand to unsnap one end of the safety strap from the left "D" ring on the body belt. Holding the end of the safety strap in your left hand, pass it around the back of the pole. Transfer the end of the safety strap from the left hand to the right hand, at the same time crooking your left arm around the pole to hold yourself in position. Then swing the end of the safety strap quickly around with your right hand and snap it onto the right D-ring on the body belt.

> WARNING: Visually check to ensure that the snap engages the D-ring. Don't depend on the sound of the keeper snapping to indicate that the snap-hook has engaged the D-ring.

You can now release your left arm gradually, so as to lean back against the safety strap (fig. 10-27).



73.313
Figure 10-27.—Working position.

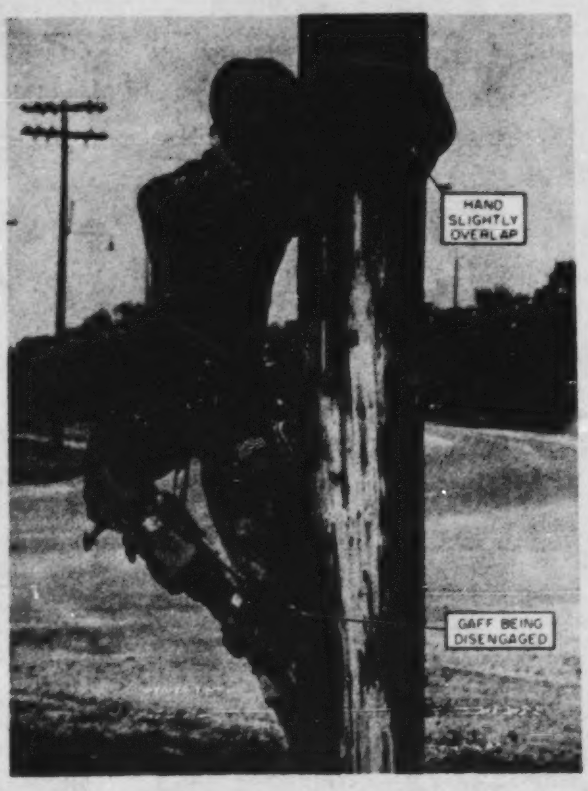
Coming Down

Before you start down the pole you must release the safety belt. Crook your left arm around the pole, and unhook the safety strap from the right D-ring with the right hand. Pass the end of the safety strap to the left hand, crook your right arm around the pole, and snap the end of the safety strap to the left D-ring.

You are now ready to descend. Break out the left gaff by swinging the left knee out from the side of the pole. Step down with the left foot to a point about 12 in. below the right; stiff-leg the left leg, and bring your weight on it to sink the gaff. Then break out the right gaff by swinging the right knee away from the pole (fig. 10-28) and proceed as formerly with the left leg. Continue this stepping-down process until you have reached the ground.

Safety In Pole Climbing

Never climb an erected pole until it has been plumbed, backfilled, and tamped. Before going



73.314

Figure 10-28.—Descending.

aloft, make sure the pole can stand your weight, and carefully make the previously described inspection of body belt, safety strap, and climbers.

The body belt contains pockets for small tools. It is important to keep the tools in these pockets. Never use the center loop in the body belt for carrying a tool, however. In case of a fall, the tool may injure your tail bone.

If you try to climb with tools in your hands, your own balance on the pole will be unsafe, and you could drop tools on someone below.

The safety strap is used to secure you to the pole, leaving your hands free to work. As you go up it is always fastened to a single D-ring on the body belt. For a right-handed man it is carried on the left D-ring.

Never use an improvised safety strap, or one that has been lengthened by the addition of rope or wire. Never attach the strap to pins or to crossarm braces. Never put the safety strap around the pole above the highest crossarm if the length of pole above the crossarm is short. The strap should never be less than 1 foot below the top of the pole.

Never wear climbers except for climbing. Be careful not to gaff yourself or anybody else.

Some additional precautions to keep constantly in mind are as follows:

1. NEVER carry tools or other objects in your hand when climbing.

2. NEVER trust pins, crossarm braces, or guy wires as supports.

3. If you are working with another man on the same pole, and he goes up first, wait until he is strapped in working position before you start up.

4. Do not depend on the snapping sound when you snap the safety strap to a D-ring. Look down to ensure that the snap is engaged to the ring.

5. If the top crossarm is near the top of the pole, do not pass the strap around the short length of pole protruding above the crossarm.

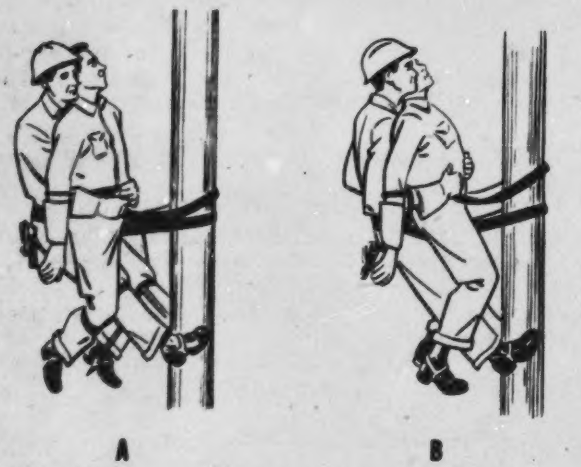
Protective Clothing and Equipment

A lineman should always wear gloves or gauntlets when tending a reel for stringing conductors. Never work with the gauntlets of the gloves turned down.

Do not wear hobnailed shoes or shoes with metal plates. When trimming trees for pole lines, wear rubbers or rubber-soled shoes for climbing. Always test safety strap and body belt before using them. Never wear a strap with stitching across it, or one mended with tape. Make all the safety checks of climbing equipment every time you prepare to go aloft.

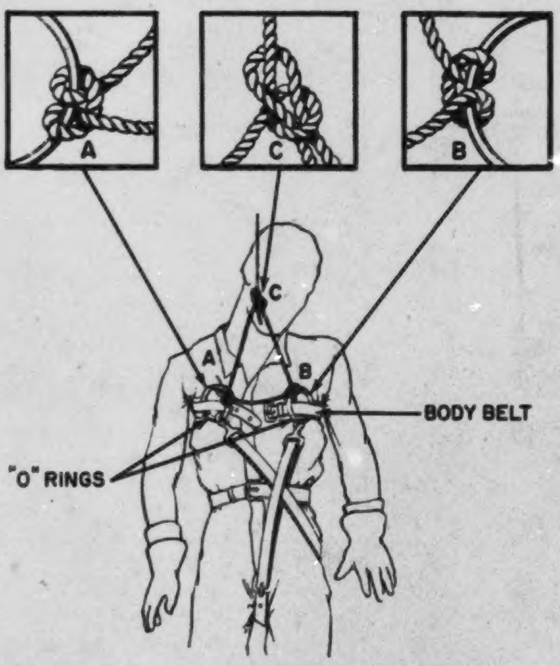
Pole-Top Rescue

When a man working aloft is shocked into unconsciousness, there are several ways of performing "pole-top resuscitation," depending on the prevailing circumstances.



4.227

Figure 10-29.—Oesterreich method of pole-top resuscitation.



73,358

Figure 10-30.—Knot details of rescue hitch using a body belt and rope.

If the victim has not received severe face or nose injuries, the mouth-to-mouth method should be given in preference to other pole-top methods, because it is easier to apply, can be started more quickly, is more effective, and can be given for a longer period of time without tiring the operator. The same rules apply for this method on a pole as for on the ground.

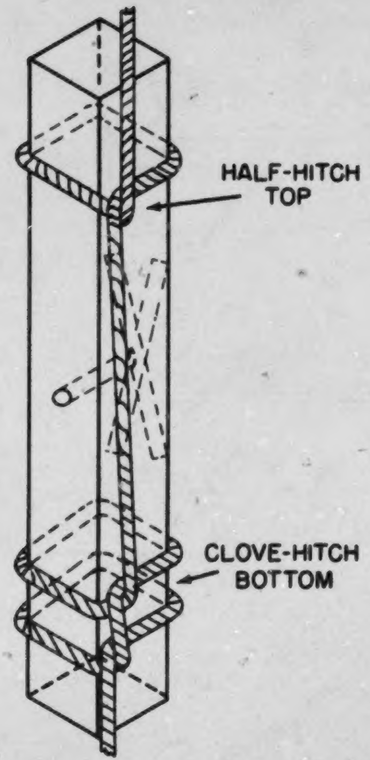
If the mouth-to-mouth method cannot be used, the next-best alternative is the Oesterreich pole-top method. This is administered as follows. First free the victim from electrical contact, making careful use of rubber insulating equipment. Then, if possible, maneuver him into vertical position and remove his climbers.

Next take a position on the pole just below the victim's feet, and with your safety belt around the pole, climb behind the victim with your safety strap between his legs. When the strap is as high between the legs as you can get it, hold the victim in straddle position on the strap as shown in figure 10-29A.

Next clear the victim's mouth of any obstructions and/or foreign matter and tilt the head back to clear the air passage. Then encircle the waist of the victim with your arms, and place both hands on his abdomen, with thumbs below the ribs and fingers touching, as shown in figure 10-29B. With your arms and hands, compress the abdomen with an upward squeezing motion. At the finish of this motion, cup your hands with the fingers depressing the abdomen just below the breastbone. Repeat this process of squeeze, pressure, and release about 12 times a minute. If the victim begins to breath, take care to keep him under control while the violent motion which usually accompanies recovering consciousness is occurring.

If you are the only other person (besides the victim) at the scene, inch yourself and the victim down the pole as you apply the resuscitation. After you complete each stroke, lean forward to slacken the safety belt (while still holding the victim on it) and move downward, even if you can only make an inch or two.

If others are available on the ground, have a line passed up and secure it to the victim (see fig. 10-30). Then secure a line to yourself. Both you and the victim should be lowered at the same time so you can continue to give artificial respiration.



73.75
Figure 10-31.—Crossarm, showing the proper way to fasten handline.

After a victim has revived, keep him as quiet as possible until he is breathing regularly. Have him lying down, of course. Keep him well covered and under constant close observation. Do not allow him to sit up, walk, or move until he is under regular medical care.

MOUNTING CROSSARMS AND RACKS

Crossarms are made in a variety of sizes, the size used depending on the voltage on the line and the number of conductors. For average use, a "six-pin" arm with four pins, occupied by conductors, is common. The size of this arm gives a good clearance space between condcutors.

Crossarms are sometimes mounted on a pole before the pole is raised and set in the ground. This gives the man doing the sighting an advantage. When a crossarm is mounted before the pole is set up, the crossarm through-bolt is set up tight, but the crossarm braces are left hanging loose. After the pole is set, the crossarm is leveled and the braces then attached. Finally, the through-bolt is set up hard.

If the crossarm is mounted after the pole is set, it is pulled up to a lineman in working position by a helper on the ground, using a handline attached as shown in figure 10-31. With the handline attached in this fashion the lineman can, after he inserts the through-bolt, cast off the upper half-hitch, and the helper on the ground can then heave the crossarm level.

Braces are usually fastened to a crossarm with 3/8-in. by 4-in. carriage bolts. Each brace comes down diagonally and is attached to the pole at the lower end with a 1/2-in. lag screw.

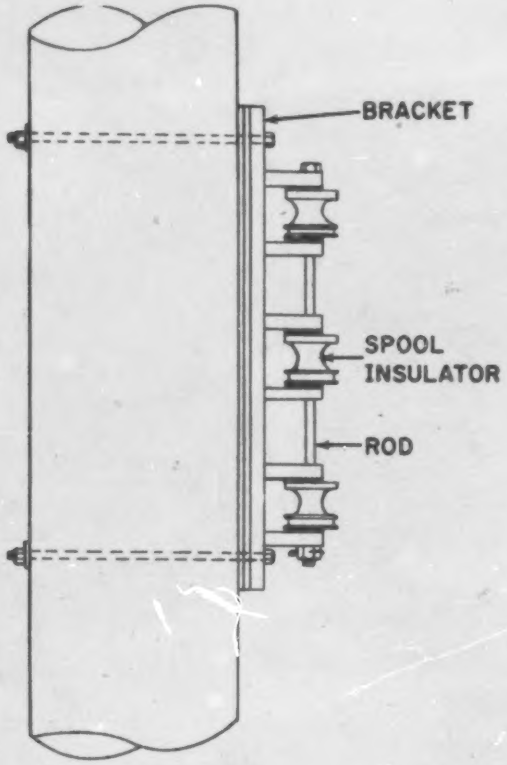
On a straight line without excessive strains, crossarms are used singly-mounted face-to-face or back-to-back, as previously mentioned. At line terminals, corners, angles, or other points of excessive strain, crossarms are doubled. Where a powerline crosses a railroad or a telephone line, crossarms should be doubled.

When double arms are used, they are fastened together at the ends with double-arm bolts. One of these is threaded all the way, and has two square washers and two nuts on each bolt between the arms. The lineman can adjust the spacing between a pair of crossarms by setting these nuts the desired distance apart on the threaded bolts.

SECONDARY RACKS

Secondary conductors may be strung on crossarms, but are usually put on secondary "racks." These racks are made in sizes to accommodate 2, 3, or 4 conductors. A secondary rack is mounted on the side of a pole (for a straight run) or on the inside of a pole (for a dead end). A rack is fastened to the pole with lag bolts on a straight line, with a through-bolt at the top and lag screw at the bottom, or with through-bolts with nuts for a dead end or where a branch line takes off from the main line. A dead end secondary rack is illustrated in figure 10-32.

Insulators are held to a rack by a rod passing through the insulators and brackets on the rack as



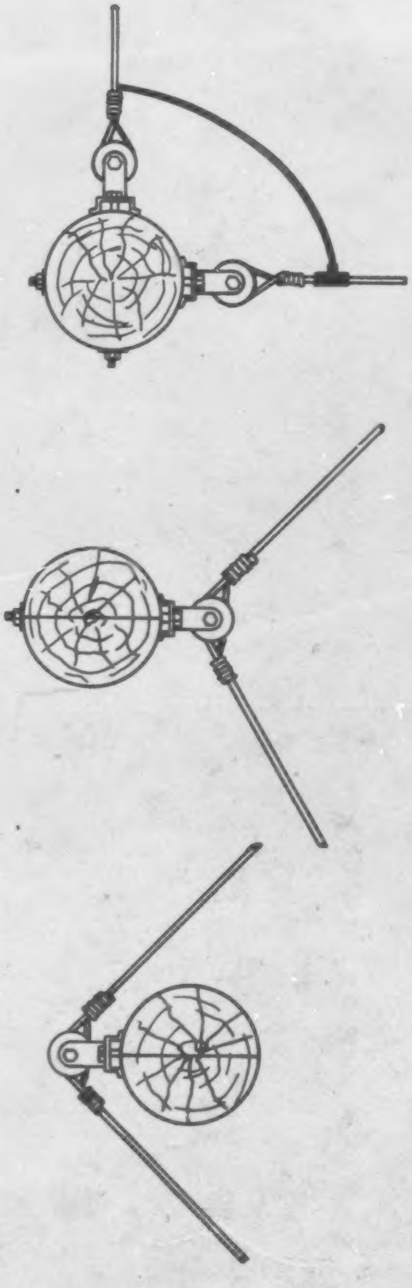
26.85
Figure 10-32.—Dead end secondary rack.

shown in figure 10-32. On a straight line or inside angle the conductor is run on the inside of the insulator. On an outside angle it is run on the outside. The conductor is always placed here with strain against the insulator. Figure 10-33 shows rack arrangements at corners and angles.

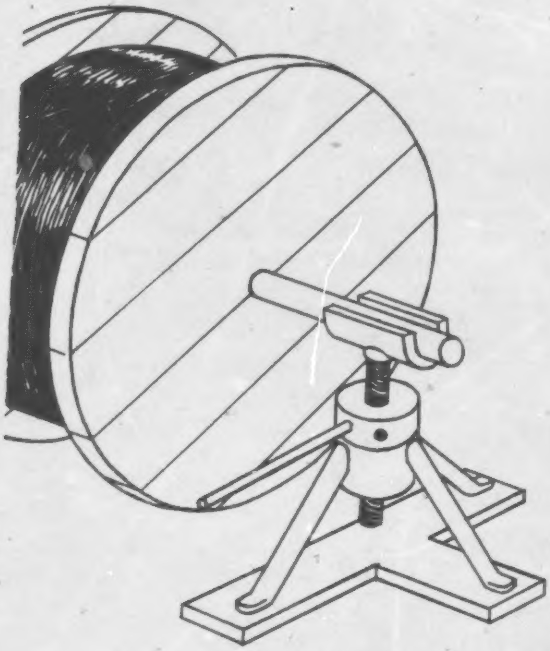
Another type of secondary construction consists of a patented bracket for holding a signal conductor. This bracket can be opened in such a way as to permit the conductor to be pulled over the insulator, which revolves like a pulley during the process. After the conductor has been pulled up to proper sag, the conductor is tied in and the bracket snapped up into vertical position.

STRINGING THE CONDUCTORS

There are various ways of stringing the conductors. One method includes placing the



73.77
Figure 10-33.—Rack arrangements at corners and angles.



73.78

Figure 10-34.—Cable reel on reel jack.

reels on a truck or trailer and driving along the line of right-of-way, unreeling the wire. This method has the advantage of not allowing the wire to drag on the ground, but in some locations you may not be able to drive a truck along the right-of-way because of rough terrain.

No matter how you string the wire, you will have to mount the reels on some support that allows them to revolve freely. This is usually done by raising a reel on cable jacks as shown in figure 10-34. A metal rod strong enough to support the reel is put through the hole in the center, and the rod and reel are jacked up on each side, with the leg of the "T" base away from the reel as shown. You may have to fasten down the bases of the jacks to keep the strain from upsetting the reel. When jacking up, it is only necessary to raise the reel just clear of the deck.

When stringing wire in rough terrain, the best method is to anchor a reel to the ground at the end of the line by means of guys run to driven stakes. A rope line is then run over the crossarms for a horizontal distance of from 1000 to 1500 ft. This line is draped on each crossarm by a lineman climbing the pole.

After the rope has been strung over the crossarms, one end is secured to the wires to be pulled, and a couple of turns taken with the other end around the winch drum on the line truck. The drum is then rotated to haul in the rope, and the wires with it. As each wire passes a crossarm, a lineman must climb the pole to set the wire in proper position and guard against twisting.

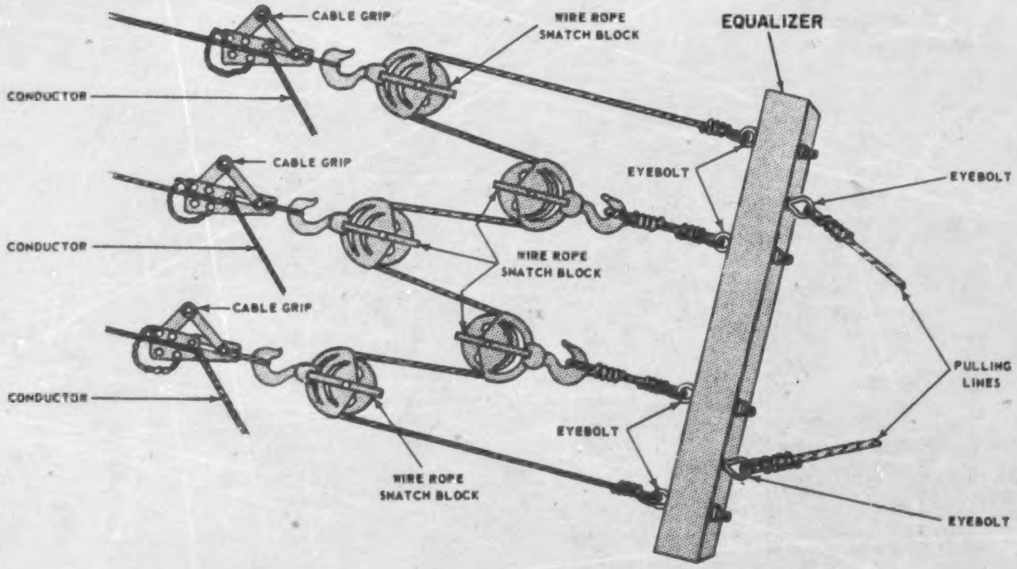
To keep a paying-out reel from revolving too fast, a brake or drage is set against the reel. This can be simply a board, held against the outer edge of the reel by a helper. As a wire or wires are being pulled, enough men must be stationed along the way to establish a chain of signal communication from the head of the line back to the line truck.

A neutral wire should always be placed on a center crossarm pin or on a pole-top pin. With a secondary rack, put the neutral wire on the top spool, so the neutral can protect the hot wires against anything that might fall from above. Putting the neutral on a center pole pin also gives the lineman a clear space around the pole to climb through—that is, it ensures that the hot wires are a considerable distance apart.

When the conductors have been hoisted in place on the crossarms and dead ended on one end, you are ready to start "pulling in"—that is, heaving on the conductors until each has been raised to proper sag. This is done with a tackle equipped with cable grips like those shown in figure 10-35. A cable grip is a clamp-type device which grips the wire tightly when a strain is applied to the grip.

When pulling two or more wires at once, it is best to use the equalizer shown in figure 10-35. This device distributes the strain equally on all the wires.

When wires have been pulled to approximately the desired sag, a lineman goes to the center span to measure the sag. Measurement at the center of each span ensures uniformity. Three common ways of measuring sag are by dynamometer, by timing vibration, and by the use of targets.



73.79

Figure 10-35.—Pulling wires with equalizer.

A lever-cam dynamometer is an instrument which is installed in the pulling line and which measures the strain of the pull. It is used in conjunction with a chart which gives the desired pull tension for a given conductor size, span length, and temperature. A traction dynamometer, also installed in the pulling line, provides direct readings on the face of the dial.

The timing-vibration process is done by striking the wire sharply near one of the pole supports, and timing by stopwatch the interval which elapses during which the impulse from the blow travels to the next pole and returns. This system is not accurate if a wind is swinging the line, or if the line is being worked on in an adjacent span.

The target-sighting method is a simple and accurate means for measuring sag. The desired sag is first ascertained from table 10-2.

Figure 10-36 illustrates the effect of temperature on the sag in a 200-ft span of 00 wire. You target-measure sag by nailing slat targets, such as a couple of pieces of wood lath, on each pole a distance below the conductor insulator equal to the desired amount of sag. A lineman then sights from one slat to the other, and the conductor is hauled up or lowered until its lowest point is on the line of sight between the slats (fig. 10-37).

After the wires are "sagged in," you allow a rest period of from 1/2-hour to 4 hours (varying according to the length of the pull), to let the wires adjust themselves to the tension in the pull. They will gradually "creep" until tension in all the spans is equalized. After they have crept to the final position you are ready to "tie in."

TYING IN CONDUCTORS

Tie wire fastens the conductor and insulator together. Conductors can be tied in various ways, but the ties shown in figure 10-38 are the ones most commonly used. Hold the tie wire tight against the insulator as you make your wraps around the insulator and the conductor wire.

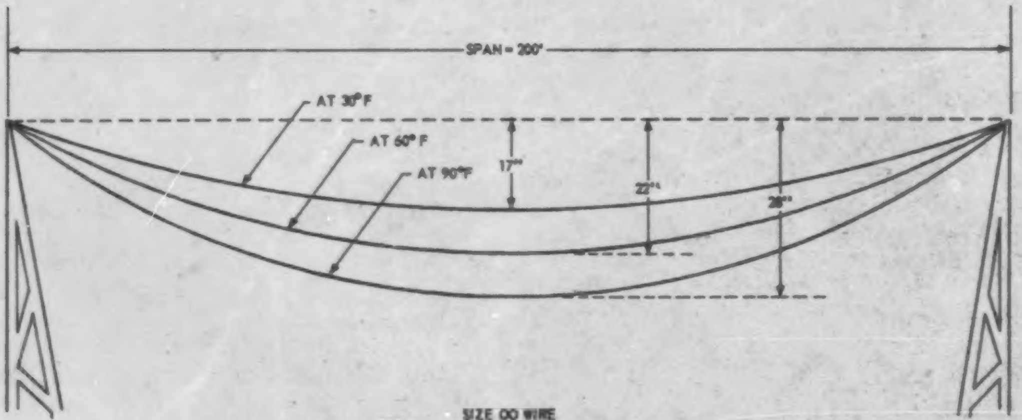
In tying in wires observe the following procedures:

Always use new, fully annealed wire for ties. Hard drawn wire is brittle and cannot be pulled up against conductor and insulator.

Table 10-2.—Sag Variation With Temperature

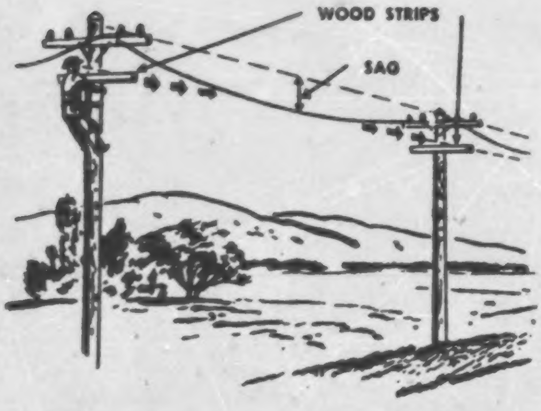
No. (awg)	Temperature (degrees F)	Sag in inches for span lengths of					
		100 ft	125 ft	150 ft	175 ft	200 ft	250 ft
6	30	5.5	8.5	13	18.5		
	60	8	12	18	24		
	90	12	17	23.5	30		
4	30	5.5	8.5	13	18.5	25	35
	60	8	12	18	24	32	42
	90	12	17	23.5	30	39	50
2	30	5.5	8.5	13	16.5	20	29
	60	8	12	18	22	26	36
	90	12	17	23.5	28	33	44
1	30	5.5	8.5	13	15.5	28.5	24.5
	60	8	12	18	21	24	31
	90	12	17	23.5	28	31	39
0	30	5.5	8.5	13	15.5	18	23.5
	60	8	12	18	20.5	23	29
	90	12	17	23.5	27.5	29.5	36
00	30	5.5	8.5	13	15	17	21
	60	8	12	18	20	22	27
	90	12	17	23.5	26	28	34
0000	30	5.5	8.5	13	14.5	16	19
	60	8	12	18	19	21	24
	90	12	17	23.5	25	27	30

73.244



73.80

Figure 10-36.—Effect of temperature on sag in 200-ft span of 00 wire.



73.315

Figure 10-37.—Adjusting sag.

Use the proper size wire. For No. 8 bare use No. 8 bare. For No. 6 or No. 4 bare, use No. 6 bare. Use No. 4 bare for No. 2 conductor. Use No. 2 bare wire for No. 1/0 through 4/0 bare conductor.

Use a piece of tie wire that is long enough to make the complete tie, with enough left over to allow grasping. After the tie is completed, cut off the excess and form a loop or eye at the end of any projecting end of the wire.

Make positive contact between tie wire and conductor to avoid chafing and to limit possibilities of causing interference with radio communications.

INTERFERENCE ELIMINATION

Powerlines may be a source of interference with radio communications. Conductors, insulators, and hardware contribute their share by means of spark discharges, localized corona discharge, and cross modulation.

Spark discharges occur when localized excessive voltage stress exists. A conductor may become partially insulated by corrosion products or an insulator partially conductive due to cracks. A third source of stress occurs when a conductor is placed with but a small air gap between it and another metallic part of a pole.

Corona is defined as "the luminous discharge due to ionization of the air in the vicinity of a conductor when the voltage gradient exceeds a certain critical value."

Cross modulation (often the result of a corroded connection which causes non-linear rectification of currents) may occur when splices are made by twisting or serving the conductors rather than the more positive mechanical splice. Additionally, when conductors of dissimilar metals are joined, corrosion will occur unless special connectors designed for the specific combination of metals are used.

Remedies for conductor, insulator, and hardware interference are relatively simple (figs. 10-39, 10-40, and 10-41). Remember, the conditions for hardware interference are set up whenever two pieces of hardware are not securely bonded to each other or are permanently separated by too short an air gap.

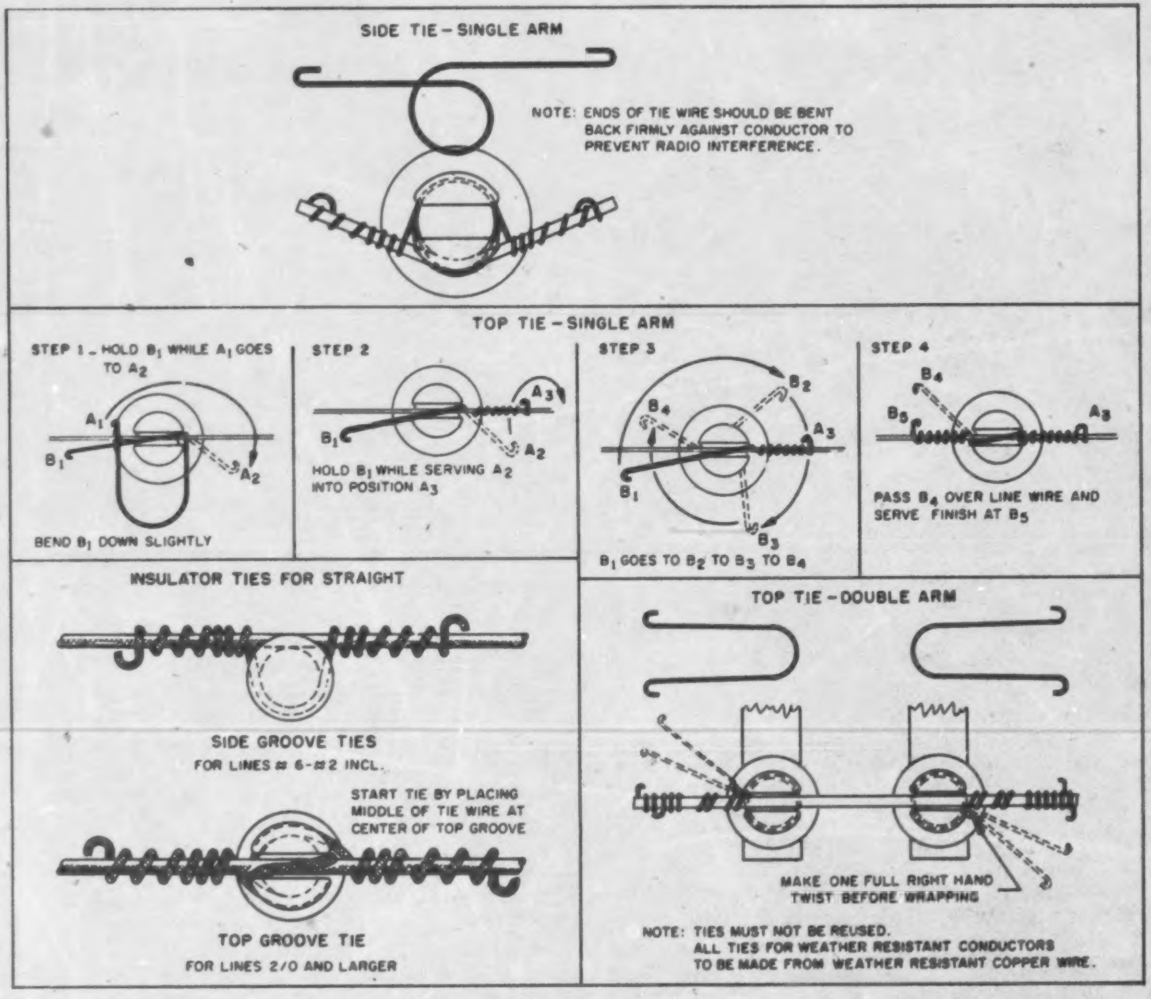
Additional specific precautions to take to minimize conductor and hardware interference include the following:

- Maintain at least 2-inch clearance through or along wood, and a 1 1/2-inch clearance through air from metal insulator pins to any other metal parts such as crossarm braces, through-bolts, square washers, molding staples, conduit, brackets for arresters and cutouts, dead end attachments, ground wires, etc.

- Permanently bond crossarm braces together on circuits greater than 5 kilovolts. Use wood crossarm braces.

- Where local electrical safety codes permit, bond metal insulator pins together on circuits above 5 kilovolts.

- Use double-coil spring washers on all bolts of attachments that support primary conductors, including primary neutral or common neutral supported on primary crossarms.
- Use ground wire clips in place of staples when attaching ground wires directly to a pole or crossarm. If metal clips are to be used on weatherproof or other types of covered ground wire, remove sufficient covering from the wire so that the metal clip will make good contact with the wire. If plastic clips are used, this procedure is not necessary.
- Ensure that ground wires, bond wires and all staples/clamps are at least 1 1/2 inches


SIDE TIE - SINGLE ARM
NOTE: ENDS OF TIE WIRE SHOULD BE BENT BACK FIRMLY AGAINST CONDUCTOR TO PREVENT RADIO INTERFERENCE.
TOP TIE - SINGLE ARM
STEP 1 - HOLD B1 WHILE A1 GOES TO A2
A1
B1
A2
BEND B1 DOWN SLIGHTLY
STEP 2
A3
B1
A2
HOLD B1 WHILE SERVING A2 INTO POSITION A3
STEP 3
B2
B4
A3
B1
B3
B1 GOES TO B2 TO B3 TO B4
STEP 4
B4
B5
A3
PASS B4 OVER LINE WIRE AND SERVE FINISH AT B5
INSULATOR TIES FOR STRAIGHT
SIDE GROOVE TIES
FOR LINES # 6-#2 INCL.
START TIE BY PLACING MIDDLE OF TIE WIRE AT CENTER OF TOP GROOVE
TOP GROOVE TIE
FOR LINES 2/0 AND LARGER
TOP TIE - DOUBLE ARM
MAKE ONE FULL RIGHT HAND TWIST BEFORE WRAPPING
NOTE: TIES MUST NOT BE REUSED.
ALL TIES FOR WEATHER RESISTANT CONDUCTORS TO BE MADE FROM WEATHER RESISTANT COPPER WIRE.

73.316

Figure 10-38.—Tying in conductors.

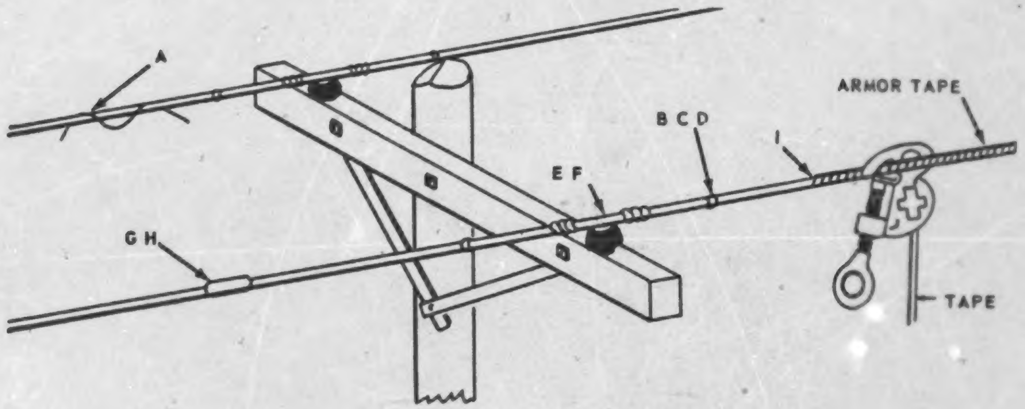
from any ungrounded metal parts such as transformer brackets, crossarm braces, and throughbolts.

- Clamp bond or ground wires only against other metal parts and with a washer or locknut.

- During construction, a lag screw with or without a double-coil washer under the head should be screwed, not driven, into place for the last 1 inch of its length.

DISTRIBUTION TRANSFORMERS

For long-distance power transmission a voltage higher than that normally generated is required. A transformer is used to step up the voltage to that required for transmission. Then, at the service distribution end, the voltage must be reduced to that required for lights and equipment. Again a transformer is used, this time to step down the voltage.


A
ARMOR TAPE
B C D
I
E F
G H
TAPE

A. KEEP CONDUCTOR CLEAR OF BITS OF WIRE, KITE STRINGS, ETC.

B. KEEP ENDS OF TIE WIRES AWAY FROM INSULATOR.

C. USE ONLY BARE, SOFT TIE WIRE.

D. AVOID SHARP POINTS AND PROTRUDING ENDS ON TIE WIRE.

E. MAKE SURE TIE WIRE IS TIGHT.

F. STRIP INSULATION FROM CONDUCTOR AND MAKE CLOSE CONTACT WITH THE INSULATOR.

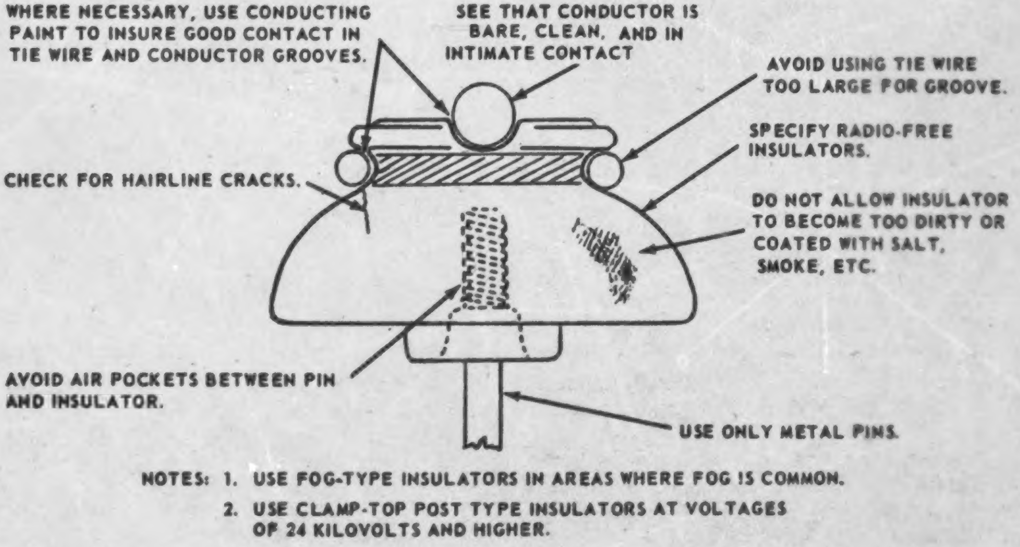
G. USE ONLY APPROVED PRESSURE CONNECTORS, AUTOMATIC SPLICE, OR SLEEVES FOR SPLICE.

H. USE SPECIAL BIMETAL CONNECTORS TO CONNECT DISSIMILAR METAL CONDUCTORS.

I. USE ARMOR TAPE AND GRADE A *NO-OXIDE* UNDER HOT LINE CLAMP ON CONDUCTOR.

73.317

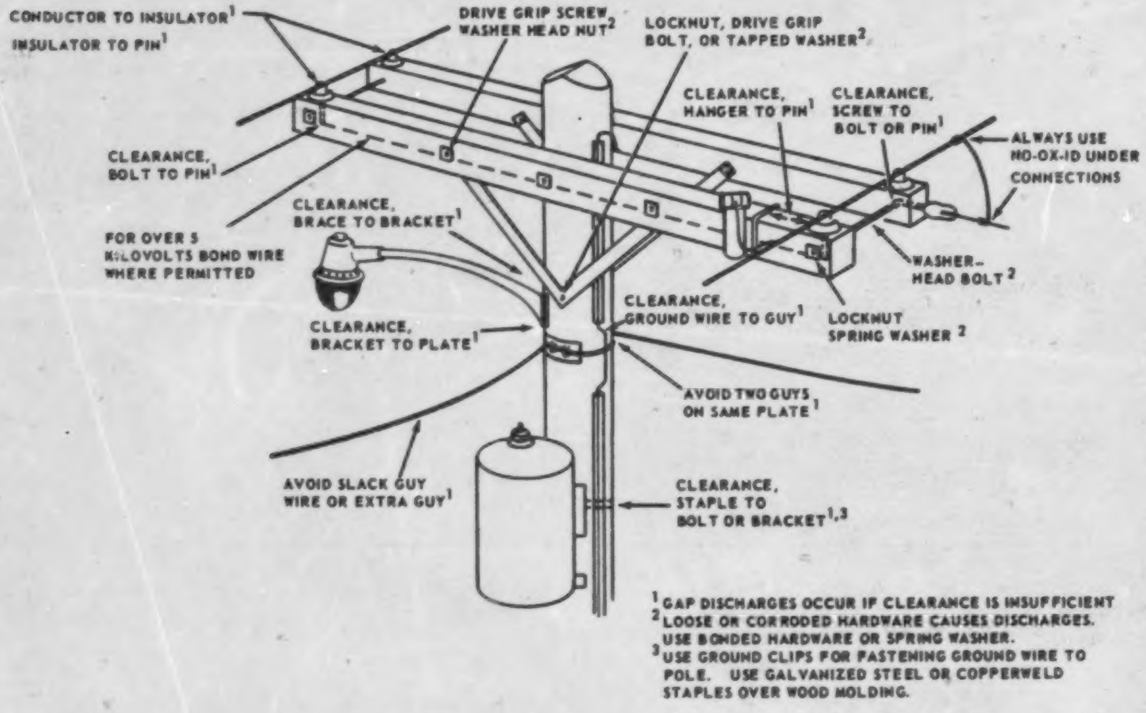
Figure 10-39.—Corrections for common sources of conductor interference.


WHERE NECESSARY, USE CONDUCTING PAINT TO INSURE GOOD CONTACT IN TIE WIRE AND CONDUCTOR GROOVES.
SEE THAT CONDUCTOR IS BARE, CLEAN, AND IN INTIMATE CONTACT
AVOID USING TIE WIRE TOO LARGE FOR GROOVE.
SPECIFY RADIO-FREE INSULATORS.
CHECK FOR HAIRLINE CRACKS.
DO NOT ALLOW INSULATOR TO BECOME TOO DIRTY OR COATED WITH SALT, SMOKE, ETC.
AVOID AIR POCKETS BETWEEN PIN AND INSULATOR.
USE ONLY METAL PINS.

NOTES: 1. USE FOG-TYPE INSULATORS IN AREAS WHERE FOG IS COMMON.

2. USE CLAMP-TOP POST TYPE INSULATORS AT VOLTAGES OF 24 KILOVOLTS AND HIGHER.

Figure 10-40.—Insulator interference corrections. 73.318


CONDUCTOR TO INSULATOR[1]
INSULATOR TO PIN[1]
DRIVE GRIP SCREW WASHER HEAD NUT[2]
LOCKNUT, DRIVE GRIP BOLT, OR TAPPED WASHER[2]
CLEARANCE, HANGER TO PIN[1]
CLEARANCE, SCREW TO BOLT OR PIN[1]
ALWAYS USE NO-OX-ID UNDER CONNECTIONS
CLEARANCE, BOLT TO PIN[1]
CLEARANCE, BRACE TO BRACKET[1]
FOR OVER 5 KILOVOLTS BOND WIRE WHERE PERMITTED
WASHER-HEAD BOLT[2]
CLEARANCE, GROUND WIRE TO GUY[1]
LOCKNUT SPRING WASHER[2]
CLEARANCE, BRACKET TO PLATE[1]
AVOID TWO GUYS ON SAME PLATE[1]
AVOID SLACK GUY WIRE OR EXTRA GUY[1]
CLEARANCE, STAPLE TO BOLT OR BRACKET[1,3]

[1] GAP DISCHARGES OCCUR IF CLEARANCE IS INSUFFICIENT

[2] LOOSE OR CORRODED HARDWARE CAUSES DISCHARGES. USE BONDED HARDWARE OR SPRING WASHER.

[3] USE GROUND CLIPS FOR FASTENING GROUND WIRE TO POLE. USE GALVANIZED STEEL OR COPPERWELD STAPLES OVER WOOD MOLDING.

73.319

Figure 10-41.—Possible sources of hardware interference and means of prevention.

Transformer theory is explained in Basic Electricity. To the discussion given there, the following may be added.

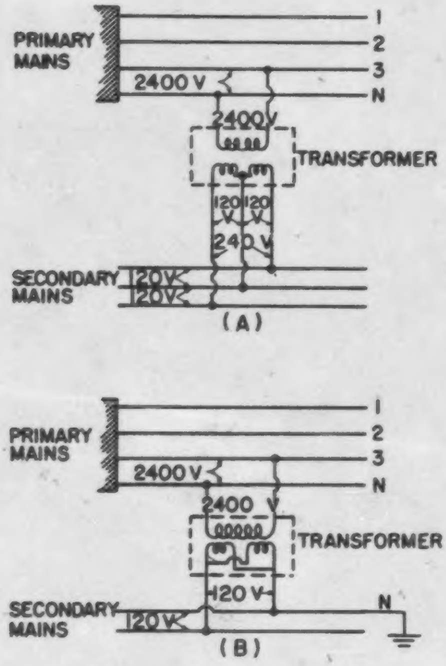
PRIMARY AND SECONDARY CONSTRUCTION

The change in voltage in a transformer depends on the number of turns of wire in the coils. The high-voltage winding is composed of many turns of relatively small wire, insulated to withstand the voltage impressed on it. The secondary winding is composed of a few turns of heavy copper wire, large enough to carry high current at a low voltage. Figure 10-42 shows a single-phase transformer, with secondary windings connected in series and parallel.

In a distribution transformer a secondary coil is wound on each leg of the laminated iron core, and the primary coil is wound over the secondary coils. The primary leads pass through a steel tank and are insulated from the tank by porcelain bushings. The secondary leads are connected to studs on a terminal block. Copper straps on the secondary terminal block permit connecting the two secondary coils in series or in parallel. From the terminal block, three secondary leads pass through porcelain bushings to the outside of the tank. An oil-level line inside the tank marks the level to which the tank is filled with transformer oil.

COOLING METHODS

There are several methods of cooling transformers, such as self air cooling, air-blast cooling, liquid-immersed self-cooling, and liquid-immersed water cooling. Self air-cooled types of transformer are simply cooled by surrounding air at atmospheric pressure, the heat being removed by natural convection (normal dissipation of heat by cooling). This type is called the dry type transformer.



73.83

Figure 10-42.—Single-phase transformer, with secondary windings connected in series and parallel.

The air-blast cooled transformer has the core and windings enclosed in a metal enclosure through which air is circulated by a blower. This type is used for large power transformers with ratings from 12,000 to 15,000 kva.

The liquid-immersed self-cooled transformer is the type previously described—that is, with coils and core completely immersed in transformer oil. In the larger sizes, the tanks are provided with external tubes or external radiators through which the oil circulates by natural convection caused by the differences in temperature in the liquid.

The liquid-immersed water-cooled transformer is sometimes used where a plentiful supply of cooling water is available. In this type, a coil of copper or brass pipe is installed near the top of the tank in the cooling oil. Water is circulated through this coil and carries away the heat from the oil as it rises in the tank.

INSULATING LIQUIDS

Insulating liquids have high insulating quality and serve two purposes: First, they insulate the coil; and second, they help dissipate the heat generated by the resistance of the windings and eddy currents in the iron core. If this heat were not removed, the transformer would operate at excessively high temperature, which in turn would damage or destroy the insulation on the coils.

Two common types of insulating liquids are mineral oil and Askarel.

Mineral oil is a nontoxic insulating liquid. It is used in different types of high-voltage electrical equipment, such as circuit breakers, switches, and transformers. Mineral oil must be kept in an airtight container, or else sludge will form. This sludge will settle in the bottom of the tank and slow the natural transfer of heat. Also the longer mineral oil is left exposed to air, the greater is the loss of insulation properties.

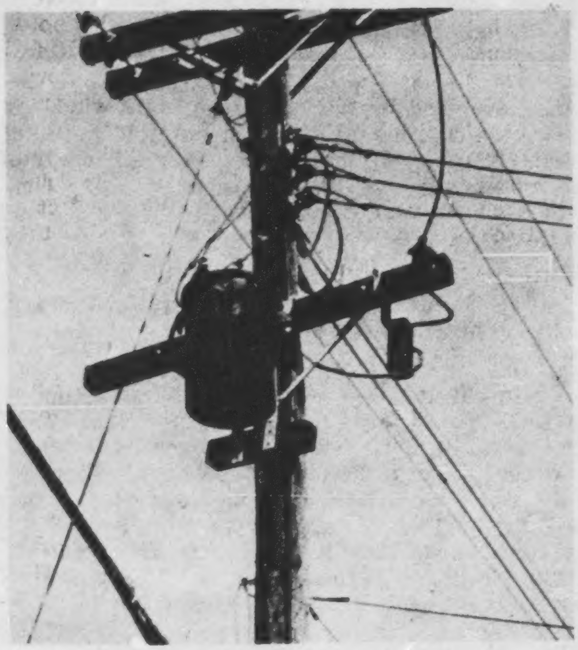
Askarel is a synthetic, nonflammable insulating liquid. It has several trade names such as Pyranol, Inerteen, Chlorextrol and Asbestol. This liquid must be handled with care because of its toxic chemical properties. Askarel is used in special transformers for applications where flammable liquids must be avoided.

Askarel may have an irritating effect upon the skin, eyes, nose, and lips. It may irritate skin abrasions or tender parts between fingers.

To protect yourself when handling Askarel, apply castor oil or approved protective cream to the face and hands. Also wear splashproof goggles. In case the liquid comes in contact with the skin, wash thoroughly with warm water and soap.

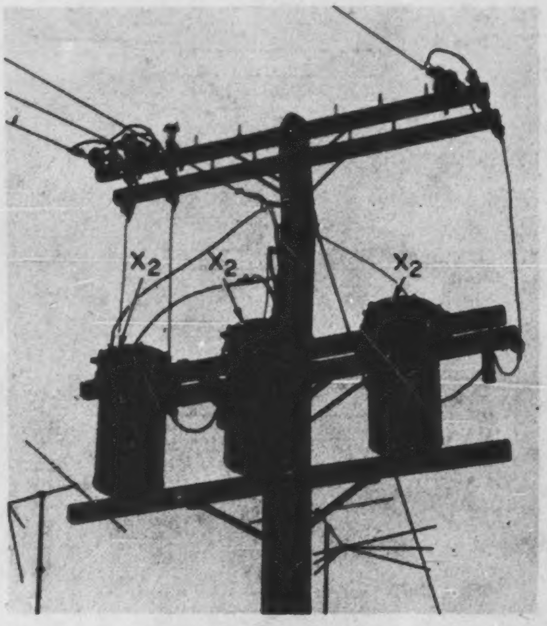
Ensure that the work space is properly ventilated before working on transformers containing Askarel.

Avoid breathing Askarel vapors. A full stomach will reduce any tendency toward nausea in the event Askarel vapors are inhaled. Make sure you eat before handling Askarel. If a job is lengthy, you should eat every 2 or 3 hours.



73.86

Figure 10-43.—Single transformer hung with crossarm brackets.



26.82

Figure 10-44.—Three-phase bank of transformers hung on crossarm.

TRANSFORMER MOUNTING

Transformers are mounted on poles in various ways, such as suspended on a bracket bolted to the pole; suspended from a crossarm with brackets; or set on a platform mounted on an H-frame.

Single-phase transformers are usually hung with a through-bolt type bracket or a crossarm type bracket. Figure 10-43 shows a single transformer hung with crossarm brackets. Fig. 10-44 shows a bank of three transformers of 25-kva capacity hung the same way.

Formerly, all banks of three transformers were hung with crossarm brackets or mounted on a platform between two poles. Because of improved materials, however, transformer capacities have been enlarged without increasing their size and weight. This means that banks of three large transformers can now be hung on a pole with a through-bolt bracket type suspension, as shown in figure 10-45.

The old method of mounting transformers on a platform required an extra pole and the added cost of building the platform. This method is still used when installing large transformers and in special job applications. Figure 10-46 shows the platform method of mounting a bank of three single-phase, 25 kva transformers, Y-connected to obtain single-phase and three-phase power.

TRANSFORMER LOAD

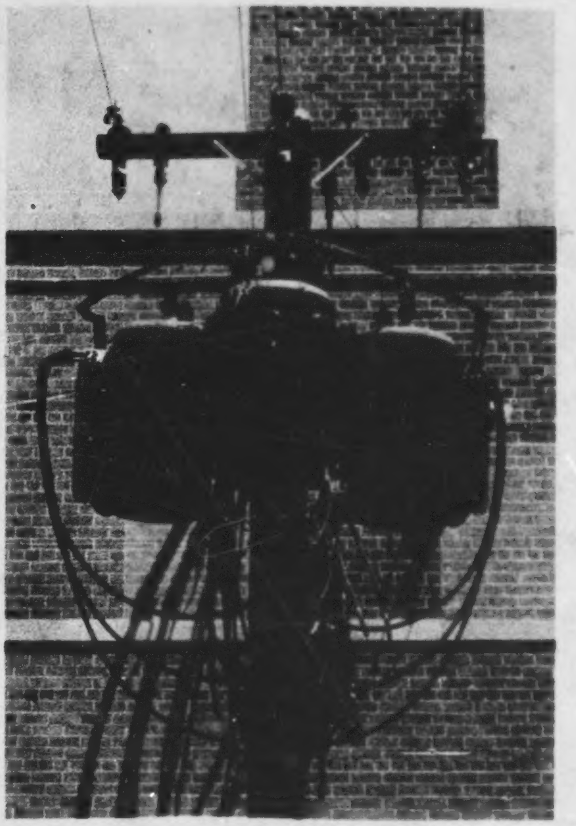
Most transformers are rated according to the kva load the transformer can carry without developing a temperature rise of more than 55°C (about 131°F), given the following conditions:

1. The transformer is operating at the rated voltage, or not in excess of 105 percent of the rated voltage.

2. The transformer is operating at the rated frequency.

3. The temperature of the surrounding air at no time exceeds 40°C (104°F), and the average during any 24-hour period does not exceed 30°C (86°F).

The 55°C allowable temperature rise is a common standard; however, the nameplate of a



73.88
Figure 10-45.—Three 37.5-kva transformers mounted with through-bolt type brackets.

particular transformer may indicate a different standard.

The proper loading of a transformer also depends on the balancing of the load on the distribution conductors. This balancing should be checked periodically with a clamp-on ammeter, to ensure that the circuit is correctly balanced. You may at times have to shift some of the load from one phase to another to keep the load balanced in the transformer.

When current is being supplied to a motor by a transformer, the kva rating of the transformer should be at least as high as the hp rating of the motor—meaning that a (for example) 75-hp motor would require a 75 kva transformer. Transformers for small motors should have a somewhat larger kva capacity than the motor kva capacity if the motors are to be run at full load or slight overload most of the time. Power input to the primary coil of a transformer is practically equal to output—meaning that the power factor is close to 1.00. However, there may be small losses, in which case P will again equal, not the product of E time I, but the product of E times I times a power factor of less than 1.00.

GROUNDING TRANSFORMERS

Grounding of a distribution system helps to prevent accidents to personnel and damage to property in the event of insulation breakdown, accidental shorting of high- and low-voltage lines, or a lightning strike.

If a high-voltage line is accidentally shorted with a low-voltage line, the current will flow through the secondary coil of the transformer to the secondary ground, which will in turn cause the primary protective device to open the circuit. In this case the primary protective device which functions is the substation circuit breaker. An accidental shorting of the primary and secondary windings in the transformer will cause the primary fuse, ahead of the transformer, to open.

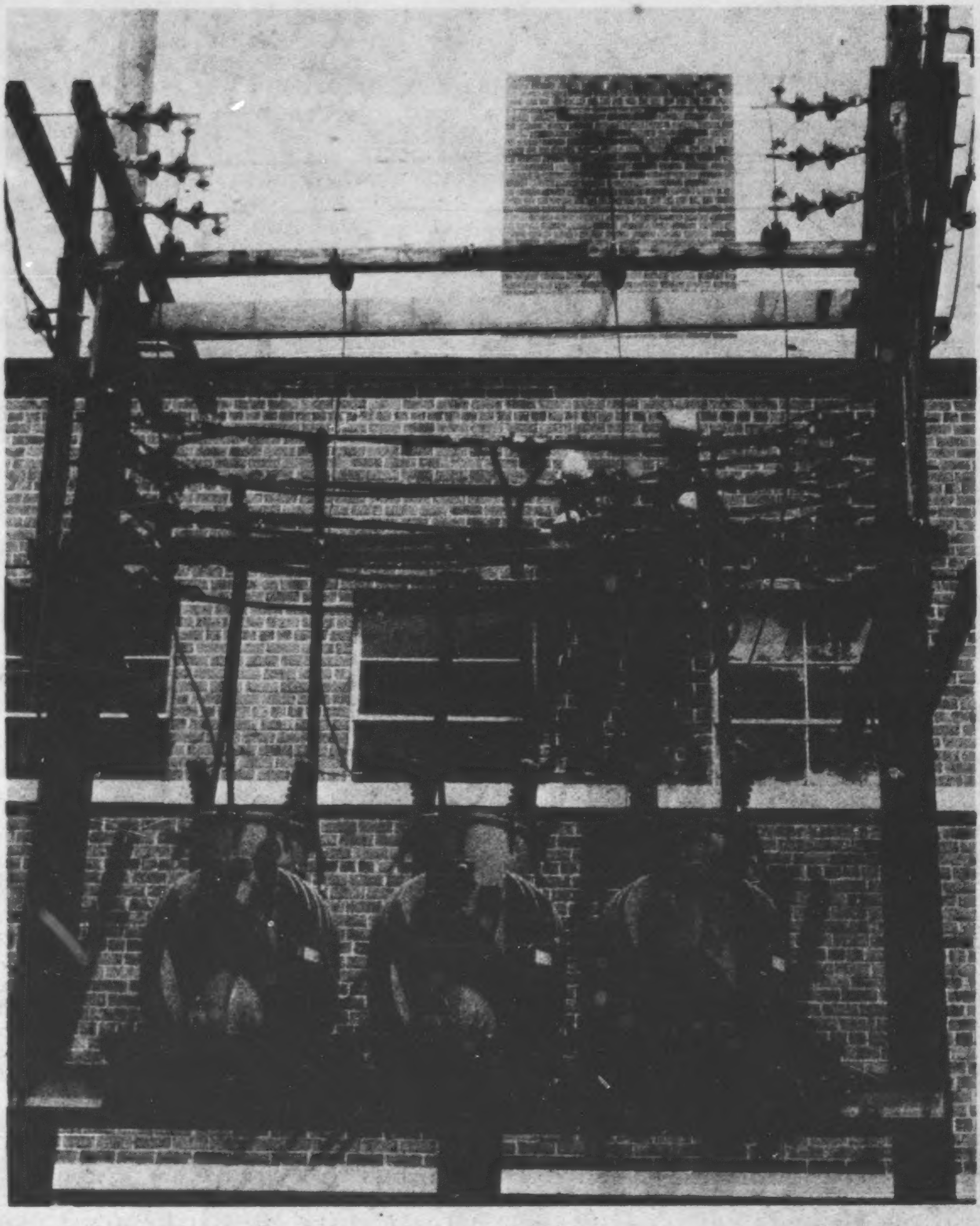
If, however, there are no ground connections, the primary voltage will be impressed on the secondary conductors, which are usually insulated for 600 volts, and considerable damage to equipment will occur. Great danger will exist for anyone touching any electrical equipment at the time.

Ground resistance must not exceed 25 ohms to ground. This resistance can be measured with various portable ground testing instruments, such as a megger. One procedure for measuring ground resistance with a megger is shown in figure 10-47.

Where ground resistance is too high, it may be lowered by one of the following methods:

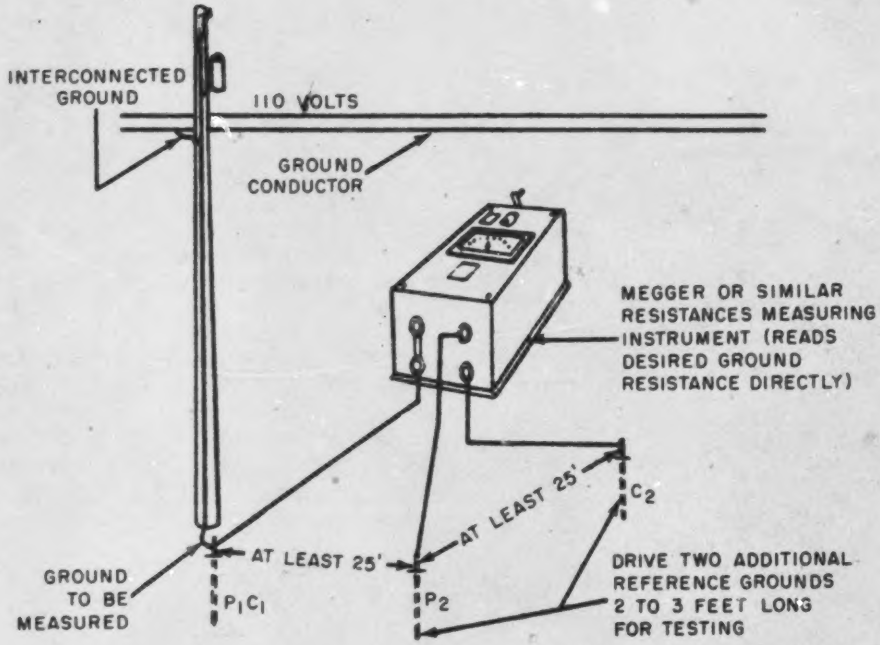
1. Driving additional rods, spacing them 6 feet apart, and then connecting them in parallel.

2. Larger rods are effective where low resistance soils are too far below the surface to be reached by ordinary length rods.



65.62

Figure 10-46.—Three single-phase 25-kva transformers mounted on H-frame platform.


INTERCONNECTED GROUND
110 VOLTS
GROUND CONDUCTOR
MEGGER OR SIMILAR RESISTANCES MEASURING INSTRUMENT (READS DESIRED GROUND RESISTANCE DIRECTLY)
AT LEAST 25'
C_2
AT LEAST 25'
GROUND TO BE MEASURED
P_1C_1
P_2
DRIVE TWO ADDITIONAL REFERENCE GROUNDS 2 TO 3 FEET LONG FOR TESTING

73.359

Figure 10-47.—Measuring ground resistance where ground wire is interconnected with grounded distribution neutral conductor.

3. The treating soil method is advantageous where long rods are impractical because of rock and other obstructions. Copperclad ground rods or 1/4-inch copper plating may be used for grounds to be treated because the heavy copper exterior resists the corrosive conditions caused by treating chemicals. Common rock salt, copper sulphate, or magnesium sulphate are used for treating the ground. These are placed on top of the soil and not in direct contact with the rod (see fig. 10-48).

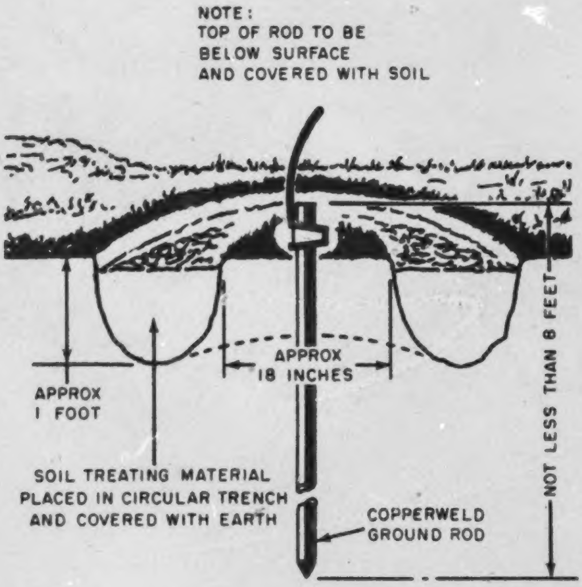
4. A combination of the above methods may be necessary and advantageous at times.

The installation of a single driven ground rod is shown in figure 10-49. The ground wire is placed on the side of the pole subject to least damage from traffic. This wire must be properly insulated from the pole line hardware where possible. The wire must also be covered with molding along the underside of the crossarm where it passes other wires on a pole and for a distance of at least 6 feet below and 4 feet above the wires. It must be covered to a point 8 feet above the base of a pole and insulated where it passes all strain guys.

TRANSFORMER POLARITY

All transformers carry standard polarity markings. The letter "H" is used to indicate the high-voltage terminals, and the letter "X" to indicate the secondary terminals. The extreme right-hand lead as you face the high-voltage side of the transformer is marked "H1," the next is marked "H2," and so on. The secondary terminals, "X1," "X2," and so on, may be in numerical order or reverse order.

Transformer polarity is important only when transformers are connected paralled for single-phase operation or are used to supply three-phase service. Figure 10-50 shows the lead markings of single-phase transformers with additive and subtractive polarity. Figure 10-51 show how to test for polarity if the nameplate is missing.


NOTE:
TOP OF ROD TO BE
BELOW SURFACE
AND COVERED WITH SOIL
APPROX
18 INCHES
APPROX
1 FOOT
SOIL TREATING MATERIAL
PLACED IN CIRCULAR TRENCH
AND COVERED WITH EARTH
COPPERWELD
GROUND ROD
NOT LESS THAN 8 FEET

73.360

Figure 10-48.—Treating grounds.

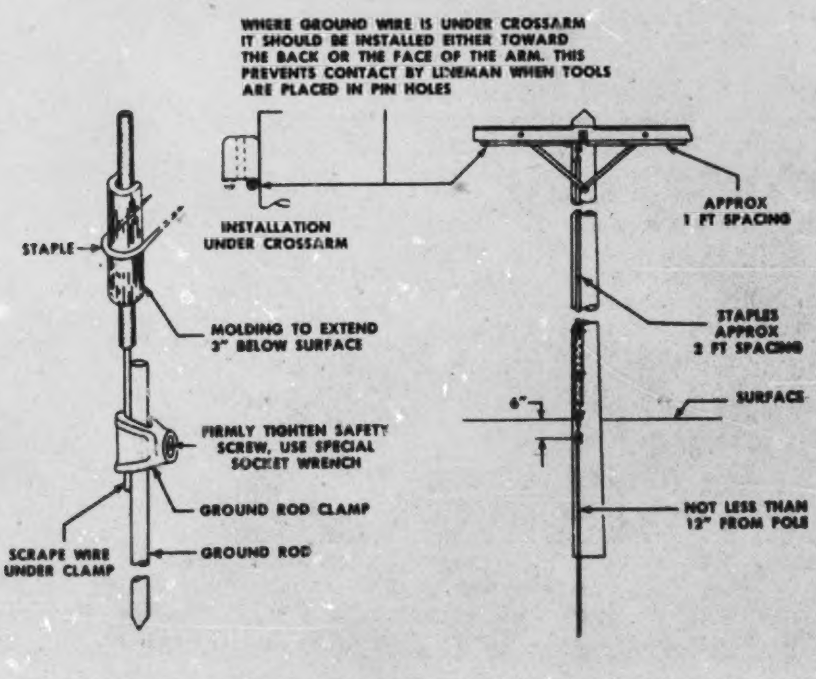
CAUTION: When making such tests, voltage must not be applied across the secondary side of the transformer because the primary voltage would then be equal to the applied secondary voltage multiplied by the transformer turns ratio. This voltage would be dangerously high to personnel and damage the voltmeter.

TRANSFORMER CONNECTIONS

Transformers are commonly connected for three-phase service by either "delta" connection or Y-connection (also called star connection).

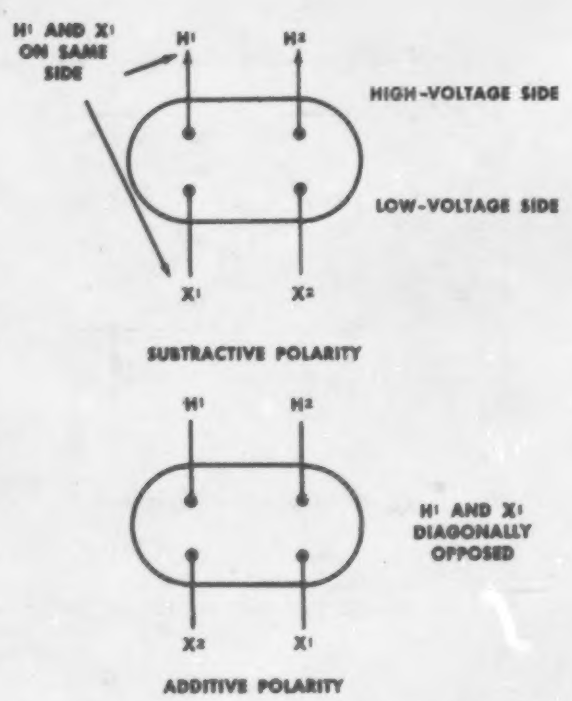
Delta connection (fig. 10-52) is made by connecting adjacent terminals of the the transformers. The right lead of one winding is connected to the left lead of the next winding. Coil voltage equals phase-to-phase voltage of the line. Coil current equals line current in each phase wire divided by 1.73.

Y-connection (fig. 10-53) is made by connecting the three right (or the three left) leads to a common neutral. The three left (or right) leads are connected to phase wires of the lines.

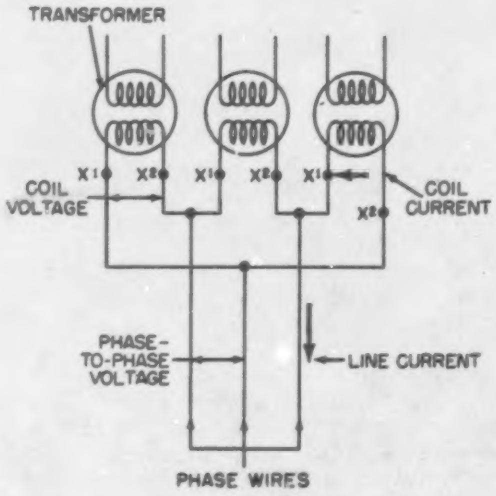

WHERE GROUND WIRE IS UNDER CROSSARM
IT SHOULD BE INSTALLED EITHER TOWARD
THE BACK OR THE FACE OF THE ARM. THIS
PREVENTS CONTACT BY LINEMAN WHEN TOOLS
ARE PLACED IN PIN HOLES
INSTALLATION
UNDER CROSSARM
STAPLE
MOLDING TO EXTEND
3" BELOW SURFACE
FIRMLY TIGHTEN SAFETY
SCREW, USE SPECIAL
SOCKET WRENCH
GROUND ROD CLAMP
SCRAPE WIRE
UNDER CLAMP
GROUND ROD
APPROX
1 FT SPACING
STAPLES
APPROX
2 FT SPACING
6"
SURFACE
NOT LESS THAN
12" FROM POLE

73.361

Figure 10-49.—Ground-rod installation for single driven ground.


H1 AND X1 ON SAME SIDE
H1
H2
HIGH-VOLTAGE SIDE
LOW-VOLTAGE SIDE
X1
X2
SUBTRACTIVE POLARITY
H1
H2
H1 AND X1 DIAGONALLY OPPOSED
X2
X1
ADDITIVE POLARITY

73.84
Figure 10-50.—Lead markings of single-phase transformer.

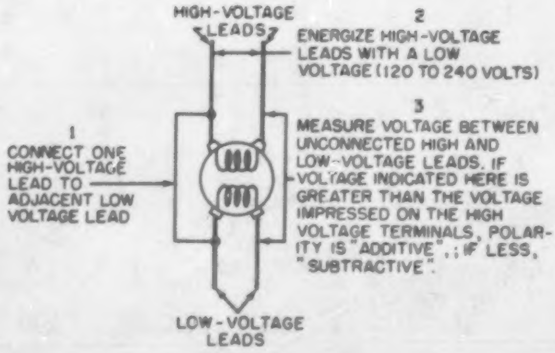

TRANSFORMER
X1
X2
X1
X2
X1
X2
COIL VOLTAGE
COIL CURRENT
PHASE-TO-PHASE VOLTAGE
LINE CURRENT
PHASE WIRES

FOR DELTA CONNECTION

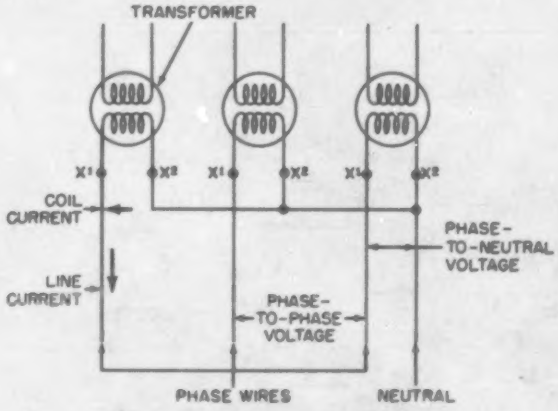
COIL VOLTAGE = PHASE-TO-PHASE VOLTAGE

$$\text{COIL CURRENT} = \frac{\text{LINE CURRENT}}{1.73}$$

73.92
Figure 10-52.—Delta connection.


HIGH-VOLTAGE LEADS
2
ENERGIZE HIGH-VOLTAGE LEADS WITH A LOW VOLTAGE (120 TO 240 VOLTS)
3
MEASURE VOLTAGE BETWEEN UNCONNECTED HIGH AND LOW-VOLTAGE LEADS. IF VOLTAGE INDICATED HERE IS GREATER THAN THE VOLTAGE IMPRESSED ON THE HIGH VOLTAGE TERMINALS, POLARITY IS "ADDITIVE".; IF LESS, "SUBTRACTIVE".
1
CONNECT ONE HIGH-VOLTAGE LEAD TO ADJACENT LOW VOLTAGE LEAD
LOW-VOLTAGE LEADS

73.85
Figure 10-51.—Test for transformer polarity.


TRANSFORMER
X1
X2
X1
X2
X1
X2
COIL CURRENT
PHASE-TO-NEUTRAL VOLTAGE
LINE CURRENT
PHASE-TO-PHASE VOLTAGE
PHASE WIRES
NEUTRAL

FOR T-CONNECTION

COIL VOLTAGE = PHASE-TO-NEUTRAL VOLTAGE

COIL CURRENT = LINE CURRENT

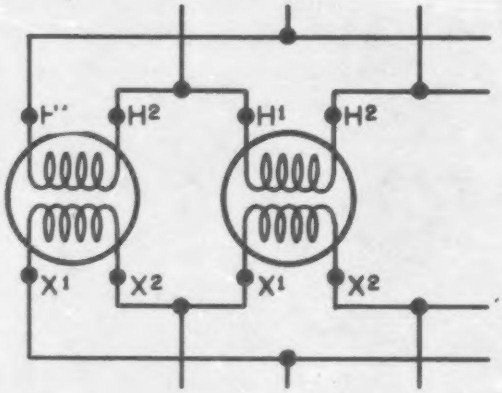
73.93
Figure 10-53.—Y-connection.

Coil current equals line current in each phase wire. Thus, if three 2400-volt transformers are Y-connected to a circuit which measures 2400-volts from phase-to-neutral or 4160 volts from phase to phase, coil voltage is 2400 volts.

Three single-phase transformers connected to a three-phase circuit are called a transformer "bank." Connections are made with combinations of delta connections and Y-connections, some of which are as follows:

A bank of transformers is "delta-delta-connected" when the primary windings and the secondary windings are both connected in delta (fig. 10-54).

In an "open-delta" connection (fig. 10-55) one of the three transformers in a delta-delta bank is disconnected because of failure. This converts the delta-delta connection to "open-delta" connection for emergency operation. The open-delta connection delivers three-phase power using only two single-phase transformers. The removal of one of the three transformers reduces the capacity of the bank, not to 66 2/3 percent of the original capacity as one might expect (100 percent minus 33 1/3 percent), but to 58 percent of the original capacity.

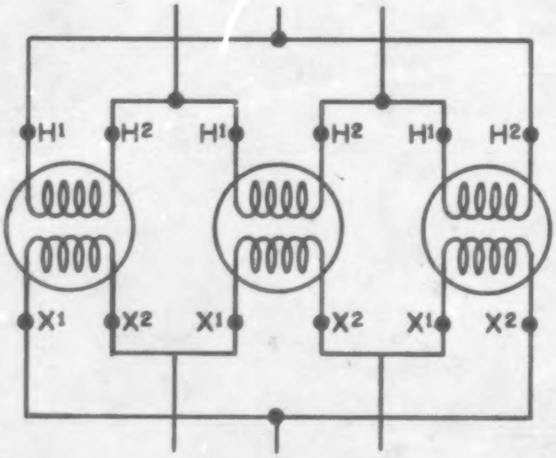


73.95

Figure 10-55.—Open-delta connection.

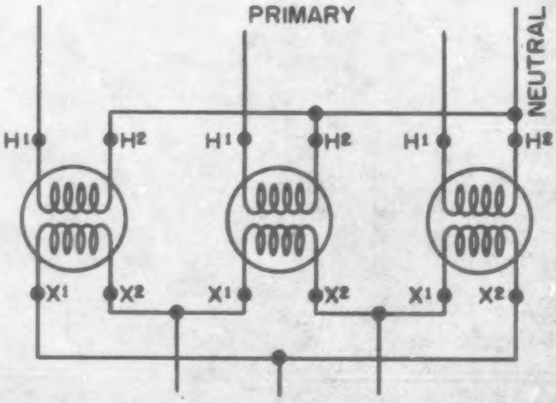
A bank of transformers is "Y-delta connected" when the three primary windings are Y-connected and the three secondary windings delta-connected (fig. 10-56). This permits the use of a primary voltage of 4160 volts with an output of 240 volts. Actually the primary voltage of each transformer is 2400 volts, as shown in figure 10-56.

A bank of transformers is "delta-Y-connected" when the three primary windings are delta-connected and the three secondary windings Y-connected (fig. 10-57). By Y-connecting the secondary, you can take care of three-phase power and single-phase lighting from the same transformer bank. The single-phase



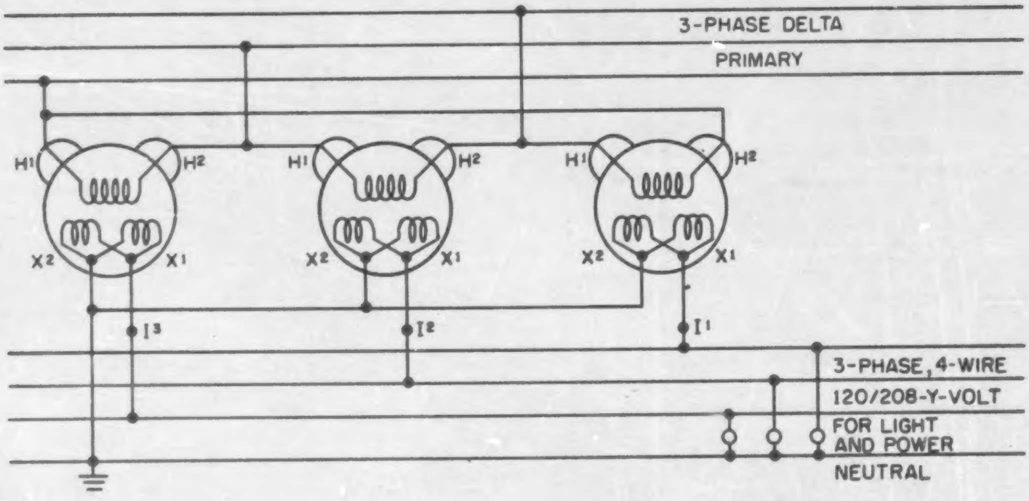
73.94

Figure 10-54.—Delta-delta connection.



73.96

Figure 10-56.—Y-delta connection.


3-PHASE DELTA
PRIMARY
H1
H2
H1
H2
H1
H2
X2
X1
X2
X1
X2
X1
I3
I2
I1
3-PHASE, 4-WIRE
120/208-Y-VOLT
FOR LIGHT
AND POWER
NEUTRAL

26.87

Figure 10-57.—Delta-Y connection.

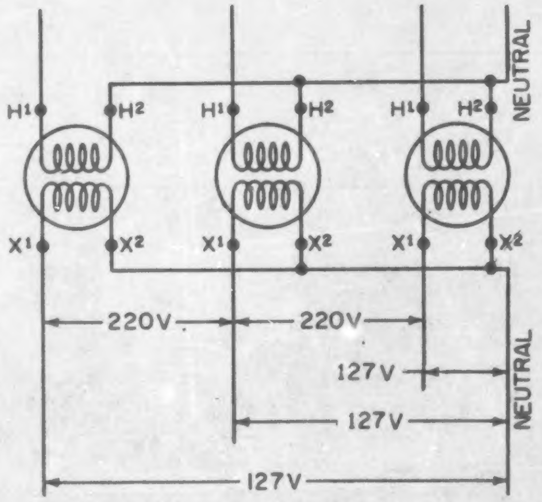
load is evenly distributed by using the neutral wire and alternate lines. You can supply a 110-volt single-phase lighting system from a delta-delta connected bank of transformers by grounding the midtap of one of the transformers; however, this is a disadvantage in that it puts the entire lighting load on one transformer.

A bank of transformers is "Y-Y-connected" (fig. 10-58) when both primary and secondary windings are Y-connected. Because the arrangement is one which causes inductive disturbance, it is seldom used.

CURRENT TRANSFORMERS

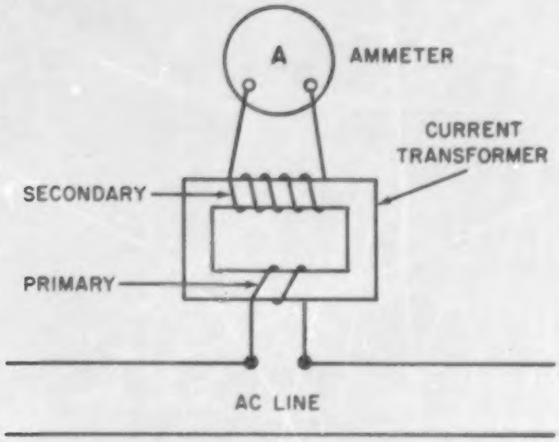
When a large alternating current is to be measured, the ammeter is not connected into the line but, instead, is connected into the circuit through a current transformer (see fig. 10-59). Information on current transformers is given in Basic Electricity, NAVPERS 10086-B. If necessary, review material on current transformers in chapter 15 of Basic Electricity before going on to the next chapter of this manual.

Standard practice today is to design all current transformers so that 5 amperes will be flowing in the secondary when full load current


NEUTRAL
H1
H2
H1
H2
H1
H2
X1
X2
X1
X2
X1
X2
220V
220V
127V
NEUTRAL
127V
127V

73.98

Figure 10-58.—Y—Y connection.



73.362
Figure 10-59.—Current transformer.

is flowing in the primary. For example, a transformer designed for 1,000 amperes in its primary would supply only 5 amperes to an ammeter in its secondary as its full load of 1,000 amperes. Such a transformer would have a ratio of 1,000 to 5 or 200 to 1.

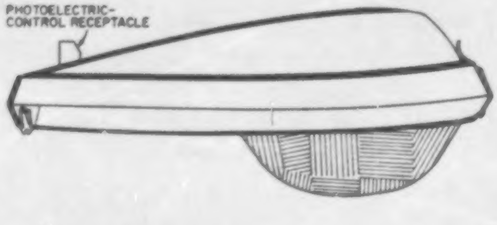
Current transformers are also used to supply current to overload trip coils of oil switches, to current coils of wattmeters, and to protective relays of all kinds.

> CAUTION: Never open the secondary of a current transformer without shorting it before removing a meter. Extremely high voltage will develop if the secondary is opened.

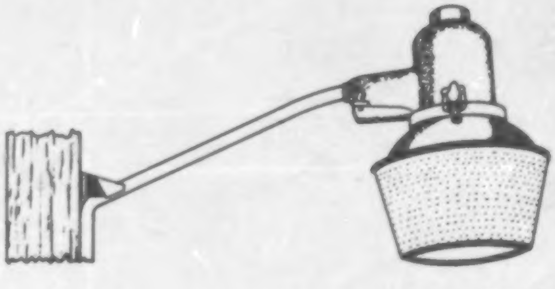
STREET LIGHTING FIXTURES

A street-lighting fixture includes a bracket or post for mounting. The mounting bracket for an overhead light usually consists of a metal pipe or framework with a pole-mounting fitting at one end and luminaire at the other (fig. 10-60). An "upsweep bracket" type of fixture is shown in figure 10-61.

> CAUTION: To prevent fragmented glass from entering your eye, when replacing a defective lamp, keep your eye level above that of the lamp.



73.265
Figure 10-60.—Common type of exterior lighting fixture.



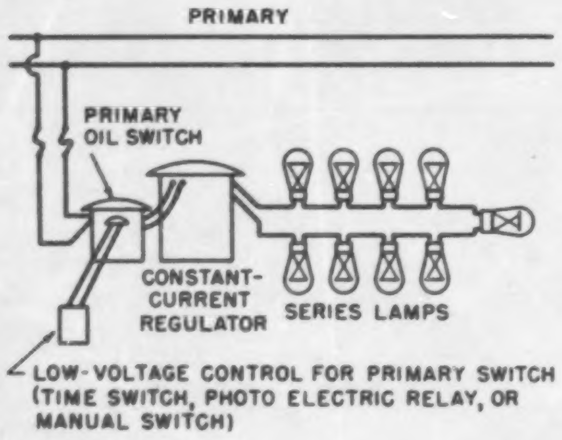
73.266
Figure 10-61.—Upsweep-bracket fixture.

STREET LIGHTING CIRCUITS

A "series" outdoor lighting circuit (fig. 10-62) is supplied by a regulating transformer which gives a uniform current, usually of 6.6 amperes, to the street lights in the circuit. Insulating transformers or autotransformers are available for stepping up the current to 15 or 20 amperes. The higher amperage permits more rugged lamp filaments, which give longer life for lamps of equal candlepower and higher lamp efficiency.

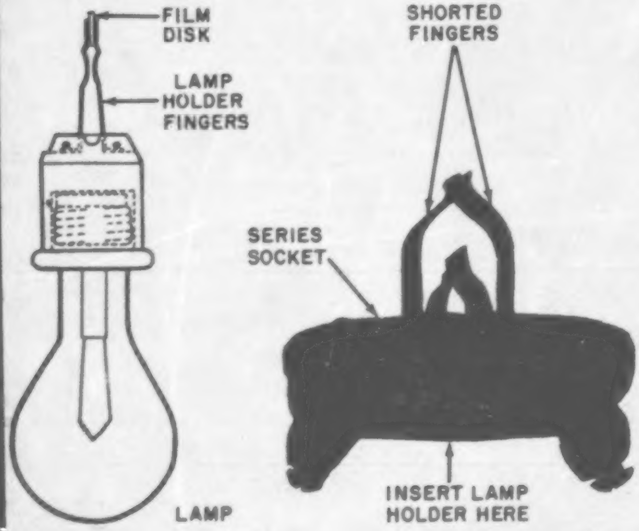
The series circuit is easily controlled, but any break interrupts the entire circuit. A film-disk cutout, along with a special lamp holder and socket (fig. 10-63), will prevent lamp failures from interrupting the circuit.

With the lamp operating, the current passes from one finger through the lamp and out the other finger. When a lamp fails, the series circuit is opened and the quarter-like film disk (between


PRIMARY
PRIMARY OIL SWITCH
CONSTANT-CURRENT REGULATOR
SERIES LAMPS
LOW-VOLTAGE CONTROL FOR PRIMARY SWITCH (TIME SWITCH, PHOTO ELECTRIC RELAY, OR MANUAL SWITCH)

73.262

Figure 10-62.—Series street-lighting circuit.


FILM DISK
LAMP HOLDER FINGERS
SHORTED FINGERS
SERIES SOCKET
LAMP
INSERT LAMP HOLDER HERE

73.322

Figure 10-63.—Series lamp, socket, and film disk.

the lamp holder fingers) is punctured. This allows current to pass from one finger through the punctured film disk, and then to the other finger—thus completing the circuit. The socket is so made that when the lamp holder is removed the fingers are short-circuited, keeping the series circuit completed.

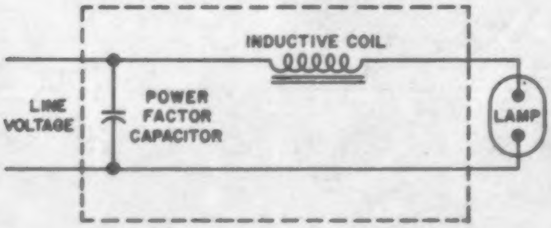
CAUTION: Do not reuse punctured film disk cutouts or substitute tape or paper for a film disk cutout.

When mercury vapor lamps are used in street lighting, a ballast or transformer is required to produce the higher voltages necessary to operate these lamps. This system is generally used in new construction because of its low maintenance cost and longer life.

Mercury vapor lamps have a quartz arc tube, which contains a small quantity of mercury and a starting gas—argon. The lamps have a negative characteristic, and therefore require a ballast for proper operation. With no ballast the current to the lamp would increase until the lamp was destroyed. The ballast actually has three functions: 1) to limit current to the lamp; 2) to provide sufficient open circuit voltage to start the lamp; and 3) to match available line voltages to lamp operating voltage.

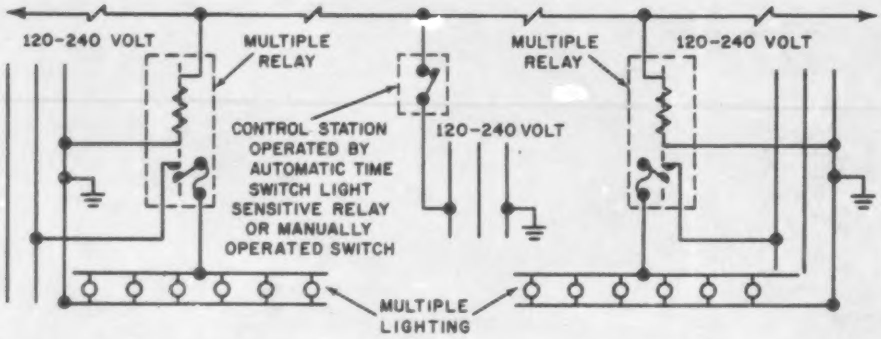
A simple mercury ballast is shown in figure 10-64. This ballast has an inductive choke coil in series with the lamp. Since this circuit is highly inductive, a low power factor of approximately 50% is obtained. The power factor may be corrected with a capacitor as shown.

A "multiple" street lighting circuit consists of a number of street lights delivering a low voltage on a secondary main. However, running secondary conductors any great distance to supply a lamp or group of lamps is impractical because of the excessive voltage drop. Figure 10-65 is an example of a multiple lighting system having a pilot control circuit.


INDUCTIVE COIL
LINE VOLTAGE
POWER FACTOR CAPACITOR
LAMP

73.363

Figure 10-64.—Mercury ballast.


120-240 VOLT
MULTIPLE RELAY
CONTROL STATION OPERATED BY AUTOMATIC TIME SWITCH LIGHT SENSITIVE RELAY OR MANUALLY OPERATED SWITCH
120-240 VOLT
MULTIPLE RELAY
120-240 VOLT
MULTIPLE LIGHTING

73.364
Figure 10-65.—Pilot circuit energized at night, extended to control multiple relays or oil switches.

The pilot circuit will turn all lights on at the same time through the use of local relays. The power needed to supply the lighting comes from local sources.

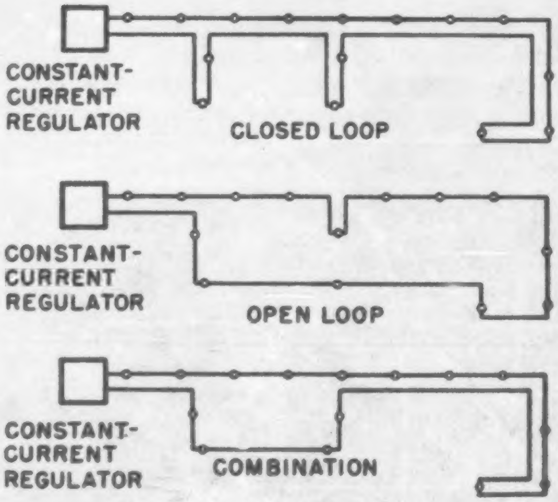
INSTALLING LIGHTING CIRCUITS

A series circuit may be installed with the return wire on the same pole or it may follow a different route. These are known as closed loop and open loop circuits (fig. 10-66). A series circuit may be installed on the same crossarm with the primary-distribution conductors (fig. 10-67). If two primary crossarms are necessary, the streetlight wires should be carried on the lower arm in the end-pin position. If two separate single-conductor street circuits are on the same lead, they should not be placed in adjacent pin positions because it would cause confusion in troubleshooting.

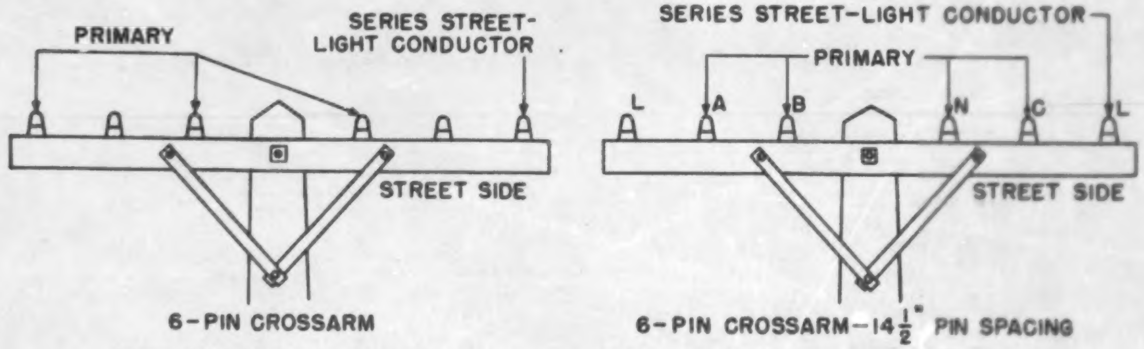
The constant-current regulator may be of the indoor or outdoor type. Most installations have outdoor regulators. The main types of installation used for these regulators are platform- or single pole-mounted. Note that any regulator larger than 20 kva should be on a platform. A single pole mounting and wiring diagram is shown in figure 10-68.

TROUBLESHOOTING

A series circuit produces many more operating problems than a small multiple circuit because of the many devices involved, and because any open in a series circuit interrupts the entire circuit. The most common and most troublesome fault is failure of all lamps in the circuit. Troubleshooting with the circuit energized gives quickest results, but personnel must be qualified for such work and use all standard safety equipment and practices. When the circuit covers a small area, check for fallen wires,


CONSTANT-CURRENT REGULATOR
CLOSED LOOP
CONSTANT-CURRENT REGULATOR
OPEN LOOP
CONSTANT-CURRENT REGULATOR
COMBINATION

73.263
Figure 10-66.—Closed and open loops in series circuits.


PRIMARY
SERIES STREET-LIGHT CONDUCTOR
STREET SIDE
6-PIN CROSSARM
SERIES STREET-LIGHT CONDUCTOR
PRIMARY
L
A
B
N
C
L
STREET SIDE
6-PIN CROSSARM—14½" PIN SPACING

SERIES STREET CIRCUIT ON ARM WITH DELTA PRIMARY

SERIES STREET CIRCUIT ON ARM WITH WYE PRIMARY

73.264

Figure 10-67.—Series circuit on same crossarm with primary distribution system.

grounds, and the like, before any sectionalizing procedures are attempted. When the circuit covers a large area, sectionalize before checking. Table 10-3 lists the various types of trouble likely to occur and gives their possible causes.

SECTIONALIZING

By locating trouble with the regulator energized you can trace the fault to a small portion of the circuit. Every electrical foreman should have a diagram for use in sectionalizing. Sectionalizing procedures for closed- and open-loop series energized circuits are as follows:

1. Closed Loop. Short circuit (jumper) both conductors near the middle portion of the circuit.

a. If lamps toward the regulator light up, open must exist in remaining portion.

(1) Divide this open portion in half and jumper it again, leaving the first jumper on.

(2) Lift the first jumper so a 1-inch gap exists. If excessive arcing continues, it indicates an open circuit and the second jumper should be moved closer to the first and another attempt made to lift the first jumper. No dynamic arc, however, indicates the fault to be beyond the second jumper.

b. If no lamps are lighted after the first short is made, the open is toward the regulator. Jumpers are removed and placed nearer the regulator and the whole procedure repeated.

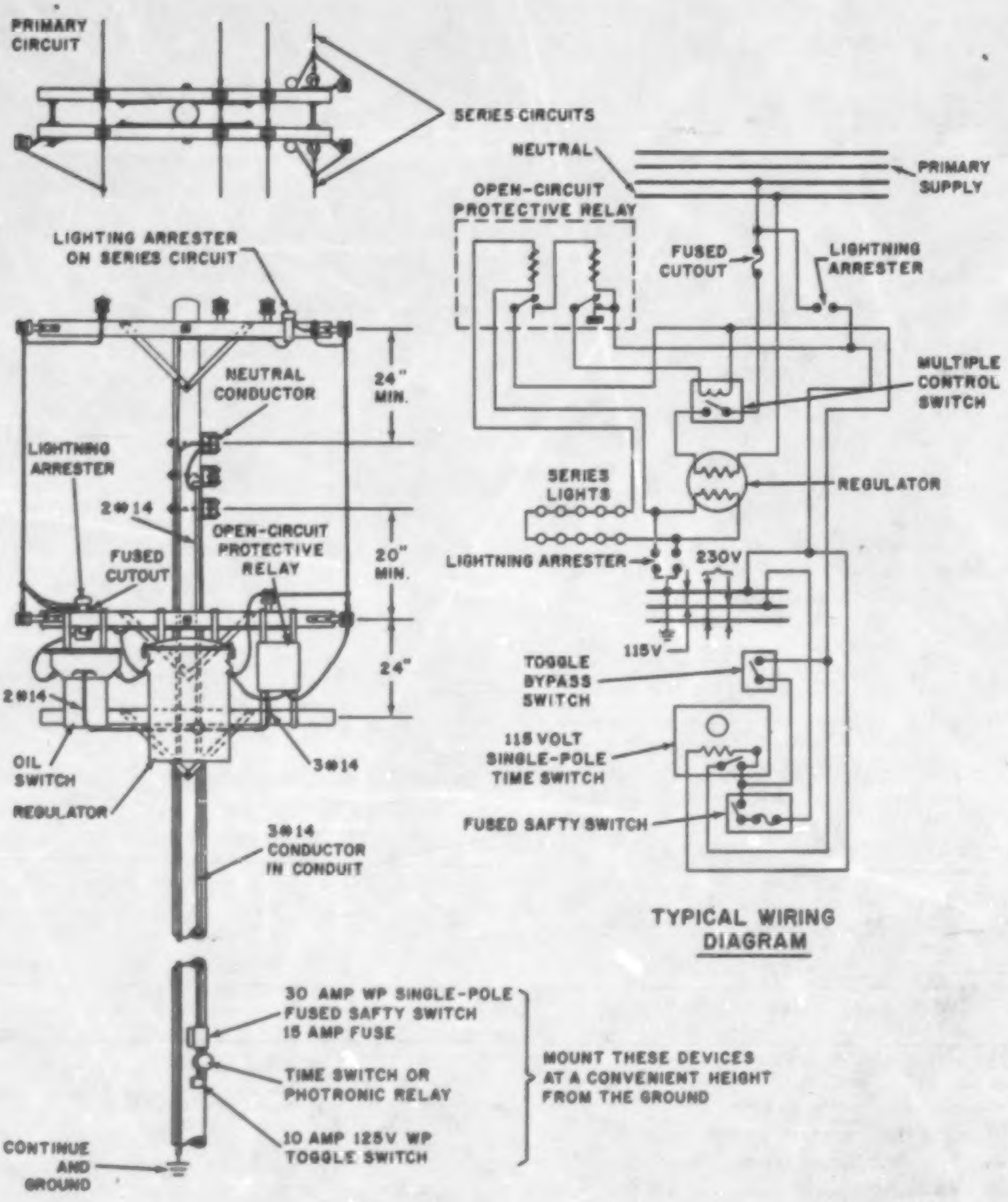
2. Open Loop. The open-loop series circuit is worked similarly to the closed loop except that, instead of shorting, the conductors may be temporarily grounded (using primary or secondary ground wire if present) at two points. This shorts out the portion of the circuit between the grounded points. The lamps in the shorted portion will not burn if it has the open, but the lamps in the remaining portion will light up.

USING A MEGGER

Faults may be located with the street circuit dead by using a 1,000-volt megger. The primary cutouts must be first opened and tagged. The megger is used in place of the jumper, with a high (infinity) reading indicating an open in the portion of the circuit being meggered. A jumper may be installed at each point meggered and after each meggering until the open has been located. All jumpers must be removed after the fault has been located and repaired.

OBSTRUCTION LIGHTING

Obstruction lights are used to indicate the existence of obstructions. These lights are red in color, with an intensity of not less than 10 candlepower. The number and arrangement of


PRIMARY CIRCUIT
SERIES CIRCUITS
LIGHTING ARRESTER ON SERIES CIRCUIT
NEUTRAL CONDUCTOR
24" MIN.
LIGHTNING ARRESTER
2#14
OPEN-CIRCUIT PROTECTIVE RELAY
20" MIN.
FUSED CUTOUT
24"
2#14
OIL SWITCH
REGULATOR
3#14
3#14 CONDUCTOR IN CONDUIT
30 AMP WP SINGLE-POLE FUSED SAFTY SWITCH 15 AMP FUSE
TIME SWITCH OR PHOTRONIC RELAY
10 AMP 125V WP TOGGLE SWITCH
MOUNT THESE DEVICES AT A CONVENIENT HEIGHT FROM THE GROUND
CONTINUE AND GROUND
NEUTRAL
PRIMARY SUPPLY
OPEN-CIRCUIT PROTECTIVE RELAY
FUSED CUTOUT
LIGHTNING ARRESTER
MULTIPLE CONTROL SWITCH
REGULATOR
SERIES LIGHTS
LIGHTNING ARRESTER
230V
115V
TOGGLE BYPASS SWITCH
115 VOLT SINGLE-POLE TIME SWITCH
FUSED SAFTY SWITCH
TYPICAL WIRING DIAGRAM

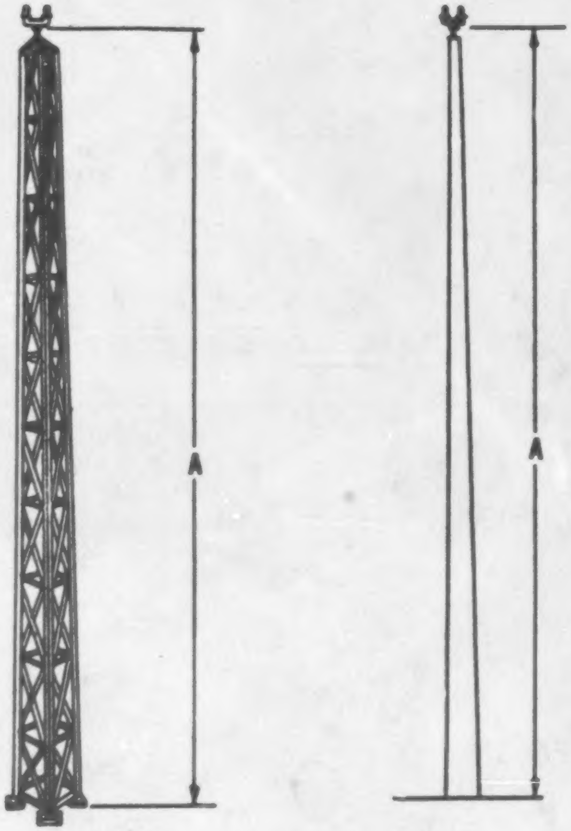
73,365

Figure 10-68.—Schematic diagram of pole-mounted installation.

Table 10-3.—Troubleshooter's Guide, Series Circuit

TROUBLE	POSSIBLE CAUSE
LAMPS FAIL TO BURN, EVEN DIMLY.	(1) PRIMARY FEEDING CONDUCTORS OPEN.
	(2) PRIMARY FUSES BLOWN.
	(3) PRIMARY FUSE CUTOUTS DROPPED OUT.
	(4) PRIMARY OIL SWITCH OPEN.
	(5) SERIES OR MULTIPLE CONTROL CIRCUIT OPEN.
	(6) PRIMARY PROTECTIVE RELAY OPEN.
	(7) STREET CIRCUIT OPEN.
	(8) PRIMARY LEADS TO REGULATOR OPEN.
	(9) DEFECTIVE REGULATOR.
LAMPS BURN DIMLY.	(1) REGULATOR OVERLOADED.
	(2) SECONDARY CONNECTION POOR.
	(3) POOR CABLE INSULATION CAUSING LEAKAGE TO GROUND.
	(4) REGULATOR MOVING MECHANISM OUT OF ORDER.
EXCESSIVE BURNOUTS.	(1) HIGH AMPERAGE (CABLE HOLDING SECONDARY MAY BE BROKEN).
	(2) LIGHTNING.
	(3) POOR LAMPS.
LAMPS BURN NORMALLY, EXCEPT FOR ONE OR TWO WHICH BURN DIMLY.	(1) FILM CUTOUT PARTIALLY FAILED.
	(2) VOLTAGE LEAKING TO GROUND.
	(3) BREAKDOWN IN INSULATING TRANSFORMER.
	(4) INCORRECT LAMP SIZE.
	(5) LAMPS ABOUT TO BURN OUT.
FILM CUTOUT FAILS BUT LAMP NOT BURNED OUT.	(1) IMPROPER CUTOUT USED.
	(2) ABNORMAL LINE SURGES.
	(3) LAMP LOOSE IN SOCKET.
WATER IN FIXTURE.	(1) BRACKET THREADS IMPROPERLY RED-LEADED.
	(2) JOINTS IMPROPERLY GASKETED.
ABNORMAL BREAKAGE OF GLASSWARE.	(1) FIXTURE OVERLAMPED.
	(2) HOLDER ACCOMMODATES GLASSWARE IMPROPERLY.
	(3) WRONG GLASSWARE FOR FIXTURE.
	(4) ABNORMAL EXTERNAL VIBRATION.
	(5) EXTERNAL DAMAGE BEYOND CONTROL.
SOCKETS AND RECEPTACLES BURNED AND PITTED.	(1) CONNECTIONS LOOSE.
	(2) CUTOUT NOT BREAKING DOWN COMPLETELY.
	(3) VOLTAGE LEAKING ACROSS SOCKET.
	(4) SOCKET FITTING RECEPTACLE IMPROPERLY.
	(5) LAMP NOT MAKING CONTACT IN SOCKET.
ABNORMAL DETERIORATION OF METAL PARTS.	ATMOSPHERE CONTAINS GASES OR VAPORS ATTACKING METALS.

73.366



A=NOT MORE THAN 150 FT.

NOTE:

WHERE "A" EXCEEDS 150FT. INTERMEDIATE LIGHTS WILL BE REQUIRED FOR EACH ADDITIONAL 150FT. OR FRACTION THEREOF.

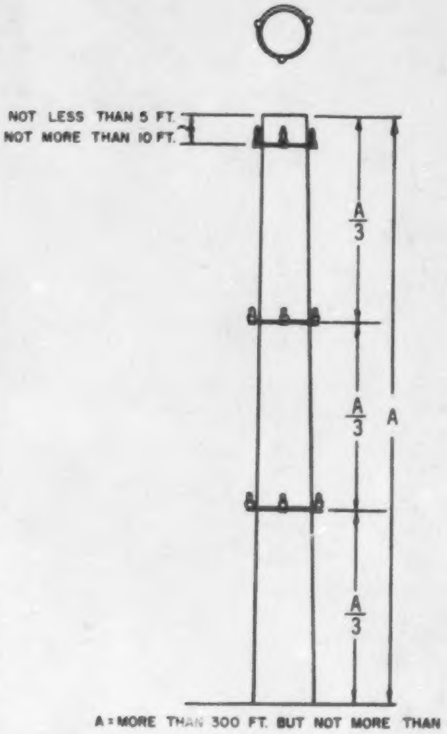
73.323

Figure 10-69.—Lighting of towers, poles and similar obstructions.

lights at each level to be lighted should be such that the obstruction is indicated from every angle of azimuth. Figures 10-69 through 10-71 illustrate these methods of lighting.

VERTICAL ARRANGEMENT

At least two lamps, either operating simultaneously or circuited so that upon failure of

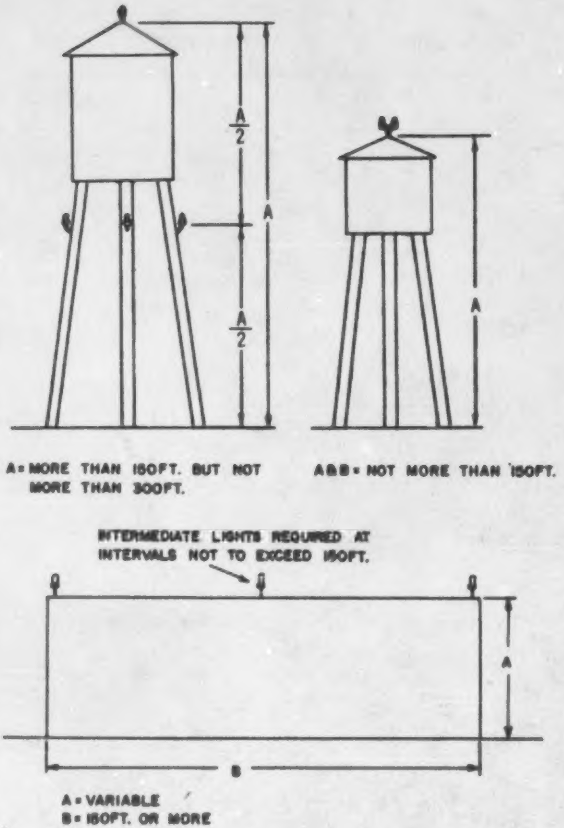

NOT LESS THAN 5 FT.
NOT MORE THAN 10 FT.
A/3
A/3
A/3
A
A = MORE THAN 300 FT. BUT NOT MORE THAN

73.324
Figure 10-70.—Lighting of smokestacks and similar obstructions.

one, another becomes operative, will be located at the top of the obstruction. An exception is made in the case of a chimney or similar structure, on which the top lights are to be placed between 5 and 10 feet below the top. Where the top of the obstruction is more than 150 feet above the level of the surrounding ground, an intermediate light or lights will be provided for each additional 150 feet, or fraction thereof. These intermediate lights will be spaced as equally as practicable between the top light, or lights, and the ground level.

HORIZONTAL ARRANGEMENT

Obstructions consisting of built-up and tree-covered areas are examples of extensive obstructions. Where an extensive obstruction or a group of closely spaced obstructions is marked with obstruction lights, the top lights will be displayed on the point or edge of the obstruction highest in relation to the obstruction marking surface, at intervals of not more than 150 feet. If two or more edges of an obstruction located near an airfield are at the same height, the edge nearest the airfield will be lighted.


A/2
A/2
A
A
A = MORE THAN 150 FT. BUT NOT MORE THAN 300 FT.
A&B = NOT MORE THAN 150 FT.
INTERMEDIATE LIGHTS REQUIRED AT INTERVALS NOT TO EXCEED 150 FT.
A
B
A = VARIABLE
B = 150 FT. OR MORE

73.325
Figure 10-71.—Lighting of water towers and similar obstructions.

LIGHTING OF OVERHEAD WIRES

When obstruction lighting of overhead wires is needed, the lights will be placed not more than 150 feet apart at a level not below that of the highest wire at each point lighted. When the overhead wires are located more than 150,000 feet from the center of the landing area, the distance between lights may be increased to no more than 600 feet.

CHAPTER 11

UNDERGROUND POWER DISTRIBUTION

Underground power distribution and communication systems are used by the U. S. Armed Forces for the following reasons:

1. Underground lines are secure against damage inflicted by high winds and storms on overhead lines in some areas.
2. Overhead lines often interfere with clear approach to aircraft landing fields.
3. Underground lines leave clear areas and open spaces for the operation of cranes and other mobile equipment.
4. Underground lines are much more secure against enemy attack than overhead lines.

This chapter presents information on installation and maintenance procedures applicable to underground power distribution systems. The structure and function of manholes and handholes, and the steps involved in pulling cable are described. Of particular interest to you is the section containing detailed cable splicing instructions. Safety precautions that you must observe are outlined, and a general overview of airfield lighting systems is given.

CONSTRUCTION

There are three principal categories of underground lines: duct lines, cables buried directly, and conduits located in tunnels. The system most frequently installed by construction battalions is the underground duct system, with its attendant manholes, handholes, duct lines, and cables.

MANHOLES AND HANDHOLES

Manholes and handholes (a handhole is essentially a small manhole) are installed at intervals along an underground line to facilitate the installation, removal, splicing, and rearrangement of the underground conductors. The conduits enter the vault of a manhole along the side walls, and devices attached to the walls support the cables inside the manhole.

Manholes are installed not more than 500 ft apart because the mechanical strain placed on the sheath and conductors of a cable may become too great during the pulling-in process. The best shape for the vault of a manhole is usually elliptical or oval to prevent the necessity for sharp bends in the cables passing through the manhole. Care should be exercised not to exceed the manufacturer's recommended bending radius for individual cables when installing or pulling them in manholes and handholes.

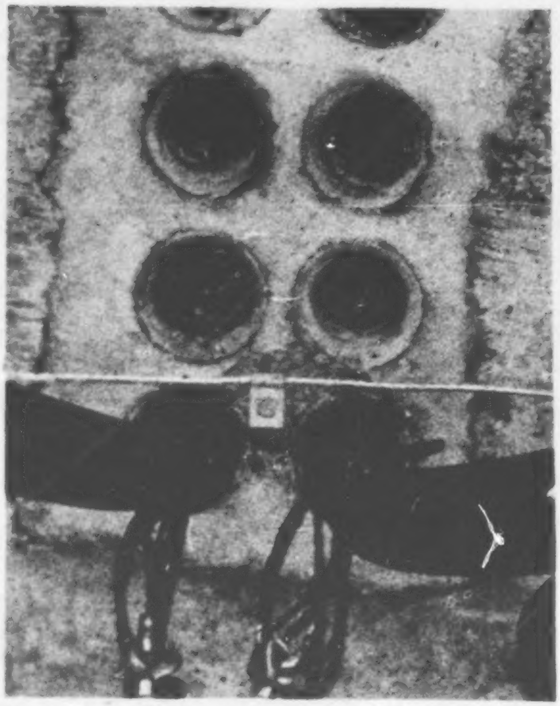
A manhole should have at least 6 ft of headroom, so that men working on cable will not have to assume stooped positions. Average inside horizontal dimensions are 5 ft by 7 ft, though a manhole may be smaller if it contains only a few duct openings. Duct openings in a manhole wall are shown in figure 11-1.

If possible, a drain to a sewer line should be installed in the bottom of a manhole. If this is not possible, there should be at least a drain hole in the floor to allow water to drain out. A cavity below the floor, off to the side, and filled with broken rock as shown in figure 11-2, will facilitate the draining process.

A handhole is used principally as a pull or junction space. It serves the same purpose as a pull box in interior wiring. A handhole is usually about 4 ft square and from 24 to 36 in. deep, with a metal cover the full size of the hole.

DUCTS AND TRENCHES

Several types of underground ducts are in general use, such as fiber, wood, vitrified tile, iron pipe, asbestos composition, and concrete. The type generally used by the Navy is a fiber type with the trade name "Orangeburg." This is a conduit which is made of wood pulp treated and thoroughly saturated with a bituminous compound. The compound contains about 6 percent



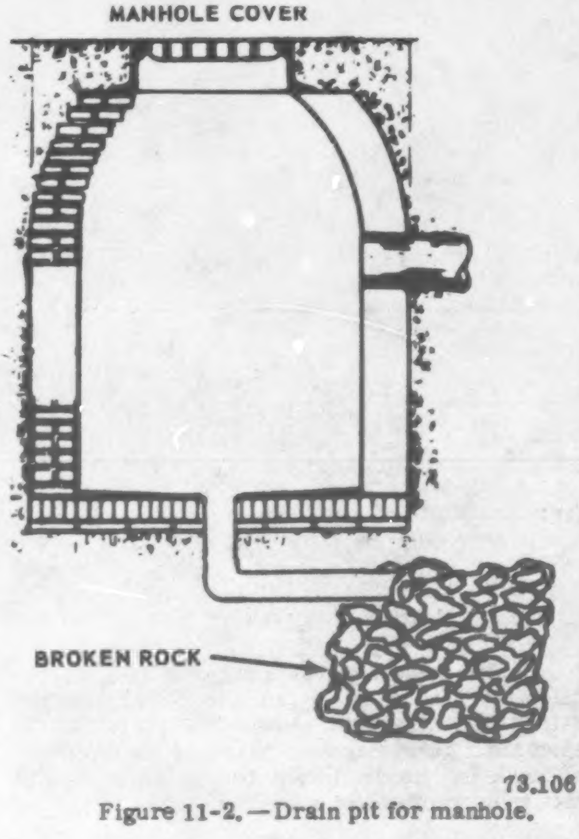
73.105
Figure 11-1.—Duct openings in a manhole wall.

creosote to prevent rotting in the ground. Sections are joined to each other with a self-aligning coupling, and can be laid in a trench very rapidly. The duct has a smooth, oily surface which allows cables to be drawn through easily. It comes in 8-ft lengths, and can be easily cut to any desired length with an ordinary wood crosscut saw.

A standard 8-ft length of fiber cut is made with a turned-down space at each end to accommodate the coupling. When you cut a length, you have to make this turn down at the cutoff end. The tool used for this purpose is called a "field tooling lathe." Figure 11-3 shows the lathe dismantled. Figure 11-4 shows the lathe on a piece of duct after making the cut. The lathe is set to cut the exact amount from the piece of duct to ensure a tight fit between the coupling and the duct. In some locations you may not have this tool available, and will have to use a coarse file or rasp. Be careful not to cut too deeply.

An underground installation will usually consist of several duct lines. Joints between sections should be staggered, so that the joints in several lines will not all occur at the same place. To ensure staggering, starting sections of different lengths are used at the starting manhole. For duct set in concrete, there must be at least 3 in. of concrete around each line of duct. This spacing is ensured by the use of spacers like the one shown in figure 11-5. The upper lines of duct must be at least 2 ft below the ground surface.

The location of the trench will vary according to ground conditions, but it should run as nearly as possible in a straight line from one manhole to the next. To ensure drainage, the line should slope downward about 1 ft but never less than 3 inches every 100 horizontal ft. If one manhole cannot be located at a lower level than the other, the line must slope downward from about the midpoint both ways toward the manholes.



73.106
Figure 11-2.—Drain pit for manhole.

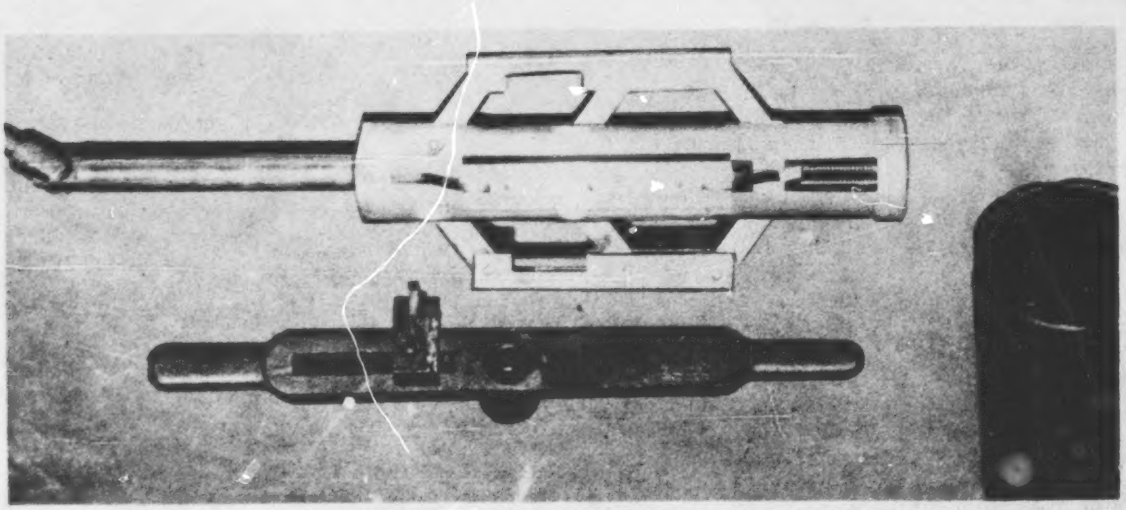


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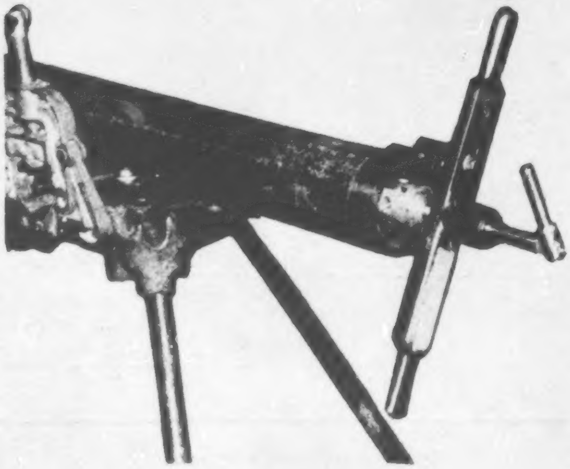
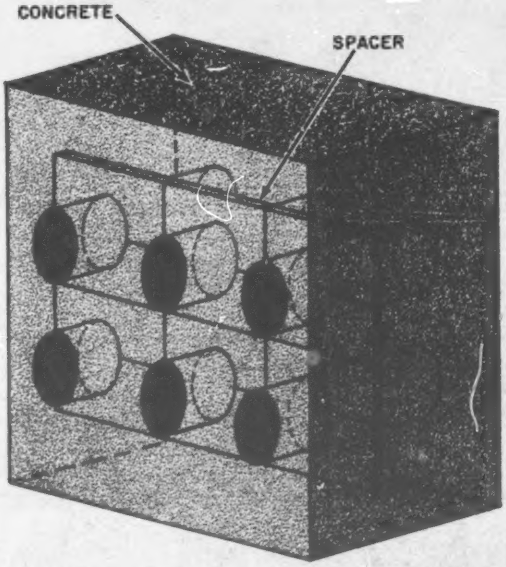
Figure 11-3.—Field tooling lathe dismantled.



73.109

Figure 11-4.—Field tooling lathe set for turning down fiber duct.

Dig the trench to the desired depth and tamp the bottom hard to ensure a solid bed for the 3-in. bottom layer of concrete. Spacers can be embedded in the bottom layer of concrete for a depth of about 1 in. before the concrete sets to ensure a solid base.



73.107

Figure 11-5.—Spacing fiber duct in concrete.

UNDERGROUND CABLE

Underground cables have various types of insulation and sheaths. Because higher voltages generate more heat, the amount of voltage carried determines the composition of the insulation.

Cables rated at 5 kv and below usually have rubber of varnished cambric insulation and a lead or rubber sheath. Those rated at 600 volts to 425 kv have oil-impregnated paper insulation and a lead sheath.

Cables rated at 5 kv and above have metallic tape shields between the insulation and sheath for mechanical protection. Exceptions to this are single conductor (1/c) cable with a lead sheath and three conductor (3/c) belted type cable.

Much of the new cable being installed is cross-linked-polyethylene (XLP) or ethylene-propylene-rubber (EPR). These are called solid type insulations. The size and number of conductors in the cable will depend on the job requirements.

PULLING CABLE

When you install a new run of duct you pull in "pulling wire," usually a 10-gage iron wire. With this wire you pull in a wire rope, to which you attach the lead-covered cable for pulling in.

Sometimes, if the duct has been in the ground a long time, the original iron pulling wire may be rusted so that it is not strong enough to pull the wire rope through. For a 400- to 500-ft run you would also have difficulty pushing a fishtape through the duct. The job can be simplified by using an air compressor to blow a chalk-line cord through the duct. To do this, take a small cloth, and tie the chalk line end to the four corners, so the cloth will function like a small parachute. With the airhose in the end of the duct and the cord free to run out, you will be able to blow the cloth through to the next opening, even on a long run of duct.

Cleaning ducts is accomplished by rodding. Quick-coupling duct rods (about 4 ft long and 1 in. diameter) are connected together with a wire brush or other duct rod leader at the head to facilitate cleaning. The rods may be pushed through manually or by means of power equipment. A 12-gauge galvanized steel wire attached to the leader is left in the duct for the cable pulling crew.

Only a very little moisture under the lead sheath is enough to cause a breakdown of the insulation between the conductors or between the conductors and the ground. For this reason, when pulling in cable, you must be very careful with short bends or any other conditions that might cause cracks or damage in the lead sheathing.

Figure 11-6 shows a way of preparing cable for pulling in a duct line. This procedure ensures that the cable will not pick up any moisture while being pulled through the duct.

Step 1: Cut back the lead sheath with four V-shaped cuts.

Step 2: Bend the lead sheath back over the cable and remove all insulation and metal tape.

Step 3: For a three-conductor cable, separate the strands of all three conductors and bend back over the sheath.

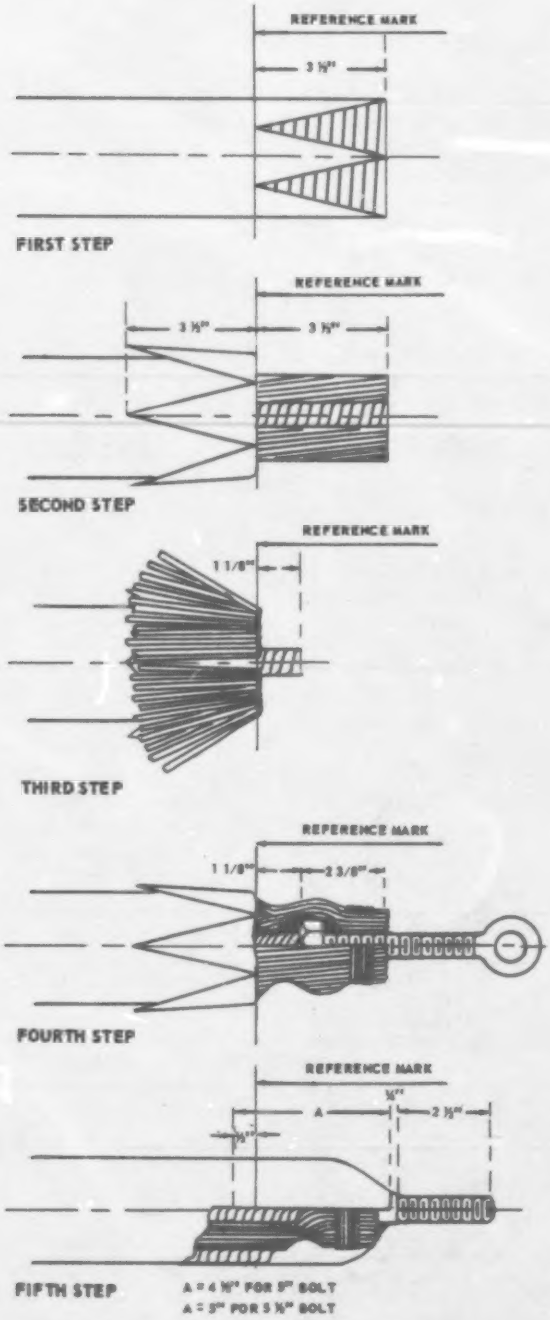
For a single-conductor cable, bend the two outer layers of strands back over the sheath, and cut the remaining strands 1 1/8 in. from the reference mark.

Step 4: Place the head of the bolt as shown. Then bend the outer strands over the assembly to fit evenly on the shank of the bolt. Bind the strands with six turns of No. 14 copper wire and sweat thoroughly.

> Note: If the strands of the outside layer do not fit evenly around the shank of the bolt, remove from the outer layer three strands equally spaced from each other before making the sweat.

Step 5: Beat the ends of the sheath forward over the solder sweat. From a point 1/2 in. beyond the reference mark, make a waterproof wipe over the sweat. The outside diameter of the wipe must not exceed the outside diameter of the cable.

Tin the head and the unthreaded portion of the bolt thoroughly before installing in the end of the cable. The threads of the bolt must be clean of solder and well greased to ensure easy running of the nut. Do not use bolts on which the threads are in unsatisfactory condition. Use great care to make the wipe waterproof.


REFERENCE MARK
3 ½"
FIRST STEP
REFERENCE MARK
3 ½"
3 ½"
SECOND STEP
REFERENCE MARK
1 1/8"
THIRD STEP
REFERENCE MARK
1 1/8"
2 3/8"
FOURTH STEP
REFERENCE MARK
½"
A
2 ½"
½"
FIFTH STEP
A = 4 ½" FOR 5" BOLT
A = 5" FOR 5 ½" BOLT

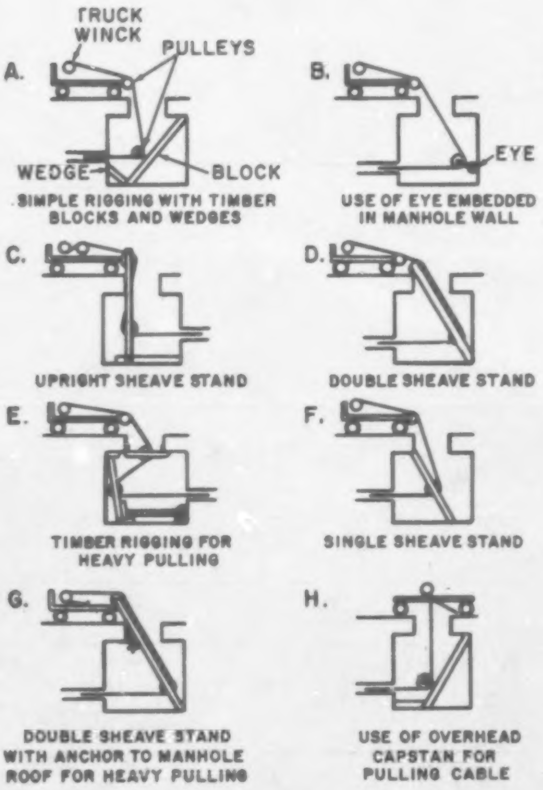
73.110

Figure 11-6.—Installing pulling bolt on lead-covered cable.

RIGGING

Figure 11-7 illustrates a number of ways to rig manholes for cable pulling. View A shows the cable pulley attached to a timber block which, in turn, is supported by a wedge. In view B, the pulley is shown attached to the manhole wall by means of an embedded eye. If you use this method, make sure that the lower sheave is in line and level with the duct in which the cable is to be pulled. To prevent injury to the cable by sharp edges, line the duct mouth with a shield.

Either of the above methods will probably be satisfactory for most of the jobs you will handle. Sometimes, however, more complex rigging is called for, especially in cases when the cable requires heavy pulling. For jobs of this nature, you will find the other views in figure 11-7 helpful.



SIMPLE RIGGING WITH TIMBER BLOCKS AND WEDGES

USE OF EYE EMBEDDED IN MANHOLE WALL

UPRIGHT SHEAVE STAND

DOUBLE SHEAVE STAND

TIMBER RIGGING FOR HEAVY PULLING

SINGLE SHEAVE STAND

DOUBLE SHEAVE STAND WITH ANCHOR TO MANHOLE ROOF FOR HEAVY PULLING

USE OF OVERHEAD CAPSTAN FOR PULLING CABLE

73.370

Figure 11-7.—Manhole rigging for pulling cable.

When pulling lead-covered cables into a long duct, use a feeding tube or bell for applying a lubricant at the duct mouth. Make sure you use the lubricant specified by the manufacturer of the cable.

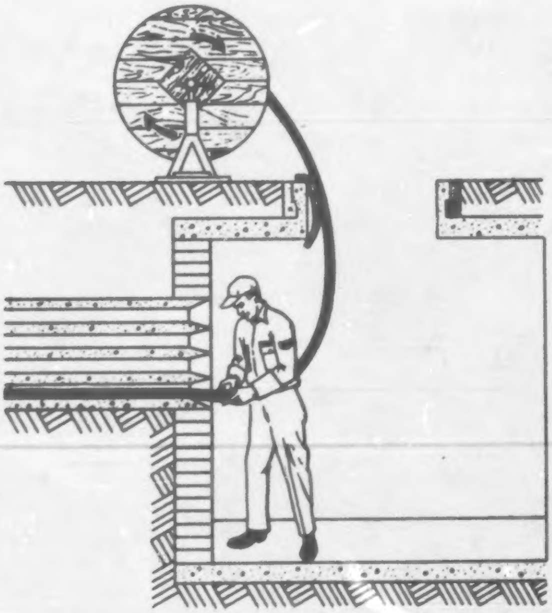
REEL PLACEMENT

Make a plank runway to support the reel for movement over areas where dirt, cinders or crushed stone might damage the cable. All cable reels are marked with an arrow indicating the direction in which they must be rolled. Comply with this arrow when placing the reel at a manhole so that it turns in the proper direction as cable is pulled from the reel. Place the reel as near as practicable to the manhole and raise it on reel jacks just enough to clear the ground. Figure 11-8 shows a reel in proper position over the manhole so that the bend in the cable is not reversed as the cable is unreeled. Notice the scuff boot at the edge of the manhole to prevent damage to the cable sheath. A section of an old tire casing can serve as a protective boot for this job.

The boards nailed to the two edges of the reel are called lagging. When the reel is in place, remove this lagging. You must be careful not to damage the cable when you pry the lagging loose. Be sure to remove any projecting nails from the edge of the reel before starting to remove cable. Next you must release the end of the cable from the reel, and you will then be ready for the main part of the job.

Assume that the winch line has been drawn into the duct as the test line was pulled out. A basket grip is now attached to the end of the underground cable on the reel. The end of the basket is secured to the cable with a tight wrap of tape or wire. A swivel connection is necessary between the basket and the pulling cable to relieve twisting of the rope.

If the cable reel is within sight of the winch, it will take four men, in addition to the winch operator, to do the job safely. One man attends the reel to see that the cable pays off the reel properly. Another man in the manhole guides the cable into the duct. Both men inspect the cable as it unreels and immediately signal "stop pulling" if a defect appears so that a



73.371

Figure 11-8. — Reel in proper position.

closer inspection can be made for possible damage to the sheath. A third man, stationed in the other manhole at the pulling end, signals "stop pulling" when the cable appears. The fourth man aboveground at the pulling-end manhole, relays signals to the winch operator. This procedure enables the winch operator to concentrate on his job of seeing that the winch line is wound into the reel properly.

The speed for pulling cable into a duct varies with the length of the duct and cable size. A single cable can be pulled in successfully at 75 feet per minute in a clear, straight duct. If you are handling more than one cable, reduce the speed to about 20 to 25 feet per minute so you can prevent the conductors from crossing as they enter the duct.

When the "stop pulling" signal is given, make sure there is sufficient slack in both manholes for splicing or terminating the cable. The slack can be adjusted with the cable basket grip. Exercise care to prevent injury to the cable insulation. Remove binding tape and basket grip from the cable. The cable is then cut to the desired length and the cutoff end in the manhole is sealed unless splicing is done immediately. The end of the cable remaining on the reel must also be sealed. In addition, check the seal on the end of the cable which has traveled through the duct, and reseal if it has broken from the strain.

SPLICING UNDERGROUND CABLE

A primary consideration in splicing underground cable is to keep moisture out of the splice. The first thing to do in the manhole, then, is to make it as dry as possible. If there is water on the floor, pump it out, because standing water can cause condensation to accumulate on your tools and on the cable.

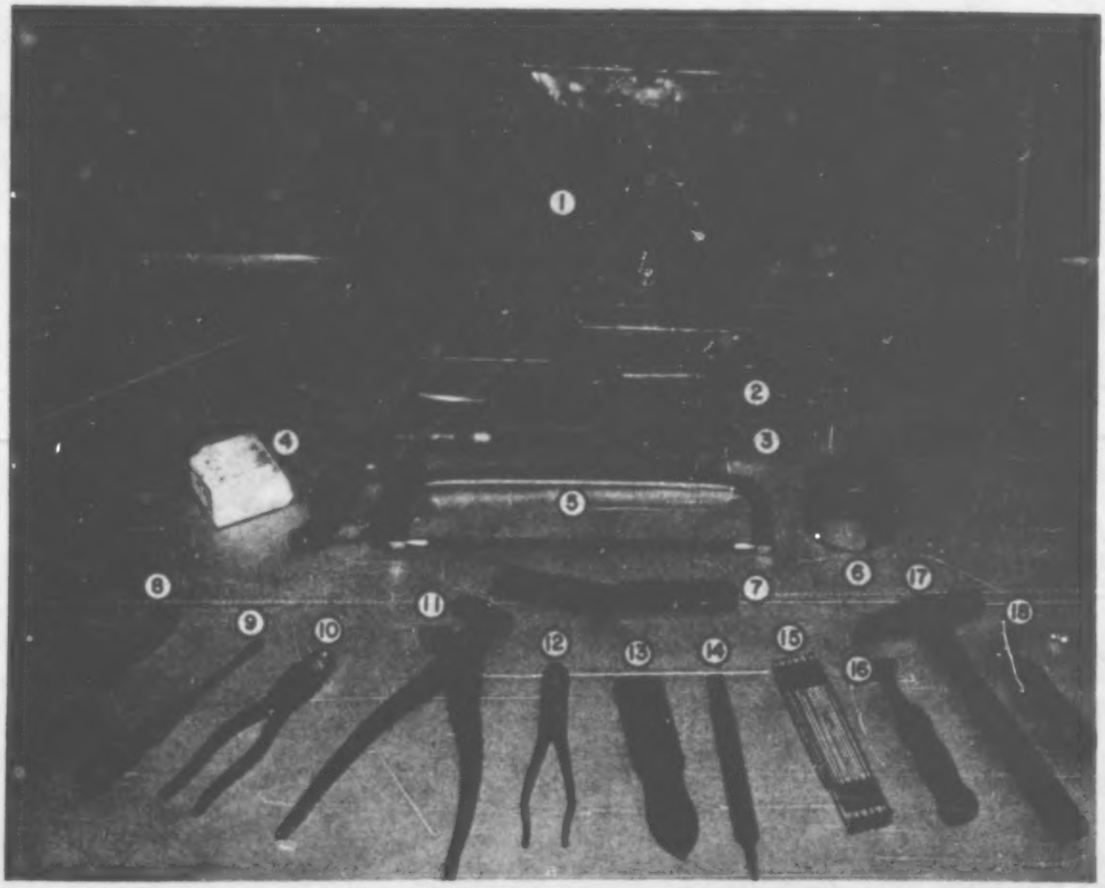
The splicing procedures outlined in the following sections apply to most types of cable. Variations in technique are dictated by differences in cable construction. Factors influencing changes are: the kind of insulation, presence or absence of a conducting shield, and whether the cable is single or multiple conductor.

PREPARING A LEAD SPLICE

The principal steps in cable splicing are (1) preparing the cable for splicing by removing the lead sheathing and insulation from the conductor and cleaning the conductor, (2) sweating the connector on the conductor and polishing the connector, (3) reinsulating the joint, installing the sleeve, and wiping the ends of the sleeve to the cable sheath, and (4) filling the sleeve with insulating compound. Each of these steps is essential, and a poor job on any one of them will result in a faulty splice. Figure 11-9 shows most of the tools used in splicing underground lead cable.

Assume that the cable shown in figure 11-10 is size 4/0, and that it is a straight joint, rubber-insulated, lead-covered cable rated at 5000 volts. The table in figure 11-10 shows that for splicing a size 4/0 cable you use a sleeve 2 1/2 in. in diameter and 11 in. long.

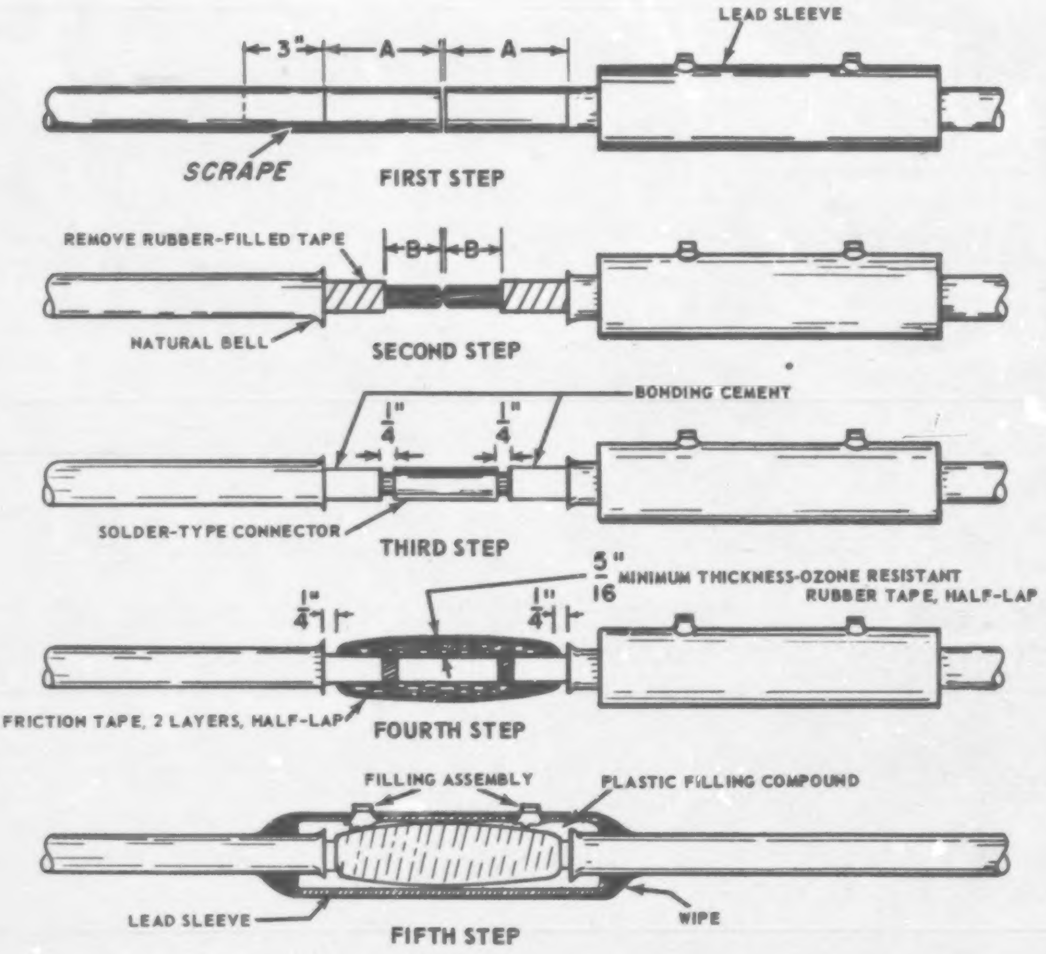
Scrape or rasp about 3 in. all around each end of the sleeve and coat with a compound called "stearing." Now use the triangular scraper, frequently referred to as a shave hook (fig. 11-9, number 18), to smooth the inside of the sleeve, so as to have a slight inside



1. Splash pan
2. Dressing tool
3. Soldering copper
4. Stearine block
5. Hack saw
6. Cotton tape
7. Cable sheath splitting knife
8. Diagonal pliers
9. 8" screw driver
10. Ringing tool
11. Parrot-nose pliers
12. Crimping tool
13. File card
14. Rasp
15. Wooden rule
16. Hook knife
17. Riveting hammer
18. Triangular scraper

73.111

Figure 11-9.—Tools and material for splicing lead cable.


LEAD SLEEVE
3"
A
A
SCRAPE
FIRST STEP
REMOVE RUBBER-FILLED TAPE
B
B
NATURAL BELL
SECOND STEP
BONDING CEMENT
1"/4
1"/4
SOLDER-TYPE CONNECTOR
THIRD STEP
5"/16 MINIMUM THICKNESS-OZONE RESISTANT RUBBER TAPE, HALF-LAP
1"/4
1"/4
FRICTION TAPE, 2 LAYERS, HALF-LAP
FOURTH STEP
FILLING ASSEMBLY
PLASTIC FILLING COMPOUND
LEAD SLEEVE
WIPE
FIFTH STEP

TABLE

CODE NO	SIZE OF LARGER CONDUCTOR AWG OR MCM	DIMENSIONS (INCHES)				
		LEAD SLEEVE		CON-NECTOR LENGTH	A	B
		I D	LENGTH			
1	6	1 ½	9	1 ½	3 ½	1
2	3	1 ½	9	2	3 ½	1 ¼
3	2	1 ½	9	2	3 ½	1 ¼
4	2/0	2 ½	11	2	4 ½	1 ¼
5	4/0	2 ½	11	2 ½	4 ½	1 ½
6	350	2 ½	11	2 ½	4 ½	1 ½
7	500	2 ½	12	3	4 ¾	1 ¾
8	750	3	13	3 ½	5	2
9	1500	3 ½	18	5	5 ¾	2 ¾
10	2000	3 ½	18	6	6 ¼	3 ¼

73.113

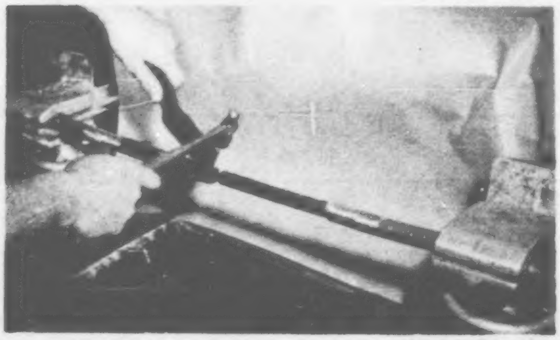
Figure 11-10.—Steps in lead cable splicing.

bevel at each end. Then slip the sleeve over one end of the cable and push it back out of your way as shown in the first step of figure 11-10.

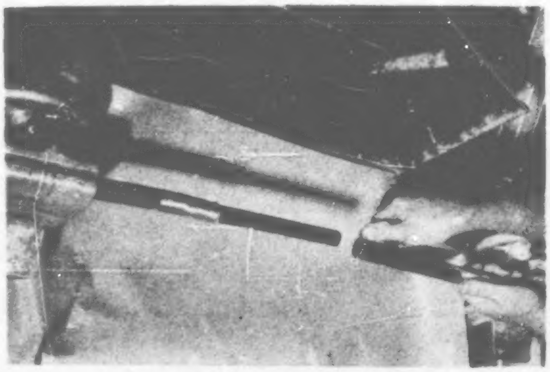
Referring again to the table in figure 11-10, you will see that the "A" dimension for a 4/0 cable is 4 1/2 in. Measure 4 1/2 in. from each end and mark this distance by a shallow ring (NOT a deep or through ring) around the sheath. Now take the triangular scraper and clean about 3 in. back from the "A" ring on each cable end. Coat the area (which is where the sleeve will join the sheath when the splice is finished) with stearine.

Split the sheath on each conductor end 4 1/2 in. back, using the cable sheath splitting knife (fig. 11-9, number 7) and a ball-peen hammer (see fig. 11-11). Hold the knife at an angle so you don't cut the insulation on the conductors, and each time you hit the knife give it a slight twist. This tends to turn up one side of the split, and helps to ensure that you do not cut or scrape the conductors.

When you have split up to the cut ring on the sheath, start pulling the sheath away from the conductors until it breaks at the ring (fig. 11-12). If you do not cut too deep a ring, a natural bell will form at the remaining end of the sheath, as shown in the second step, figure 11-10. The bell prevents any rough edge from cutting the insulation, and also allows compound to flow under the sheath and give better protection. First take a roll of cotton tape and make three wraps around the exposed insulation from 1 1/2 in. back from the end of the conductor to the sheath. Put the protective heat shields on the conductors by sliding them over the insulation (fig. 11-13). Then remove the belt insulation back to the cotton.



73.114
Figure 11-11. — Splitting sheath with cable sheath splitting knife.



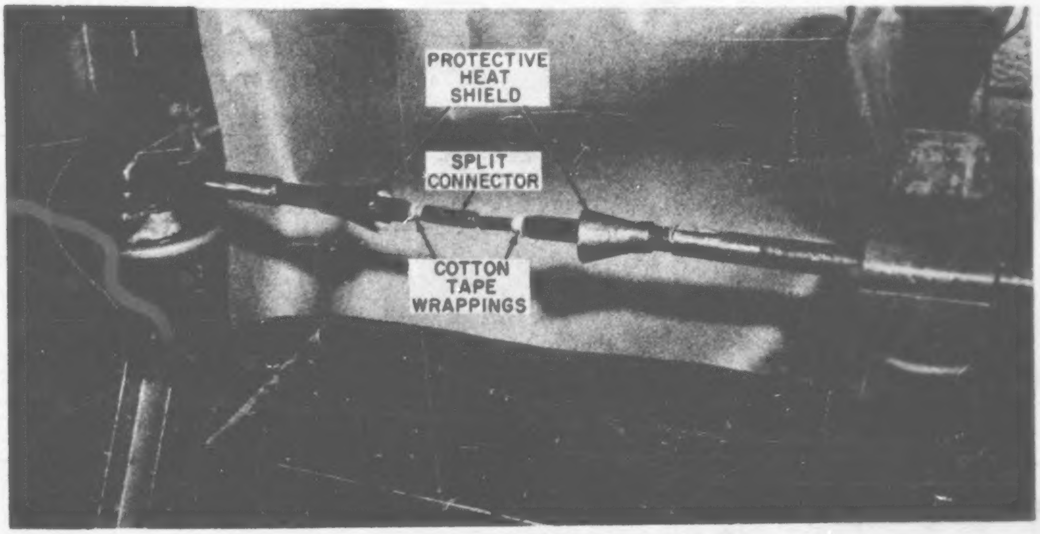
73.115
Figure 11-12. — Removing sheath from cable.

Splicing Conductors

Before you make the splice, you should refer to a bill of material like the one shown in figure 11-14. The table shown in figure 11-10 indicates that for a size 4/0 cable you use code 5. In figure 11-14, then, it is the column under code 5 (fourth column from the right) that contains material quantities for the splice in a 4/0 cable.

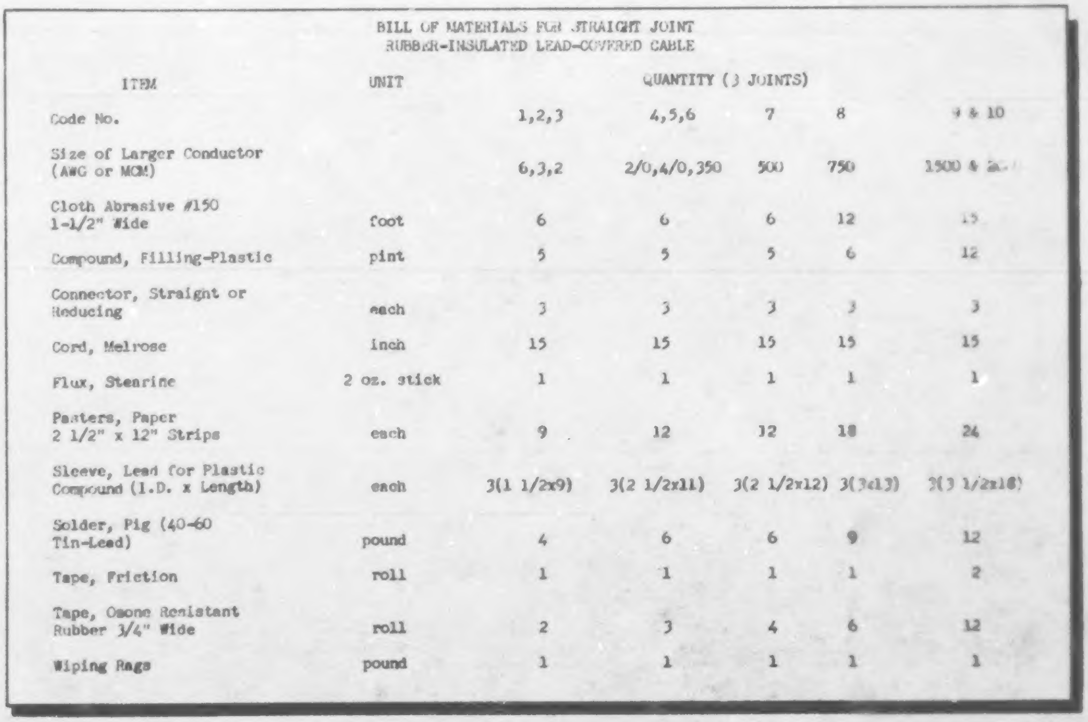
You are now ready to remove the rubber insulation on the ends of the conductors where the connector will be sweated on. For a 4/0 cable, this means 1 1/2 in. from each end (distance "B" in fig. 11-10). Cut 1 1/2 in. of rubber from each of the ends, remove the cut off insulation and pencil the insulation on each conductor end by tapering. Clean the exposed copper conductor very thoroughly with a small strip of emery cloth.

Now slip the connector onto the cable ends. This connector is a split copper sleeve, well tinned inside and outside. Figure 11-15 shows the connector and the materials used to splice it to the conductors. You may have to form the cable ends to get the connector over them, but do not spread the connector. When you have it centered on the ends, there should be a space



73.118

Figure 11-13. — Installing connector on conductor.

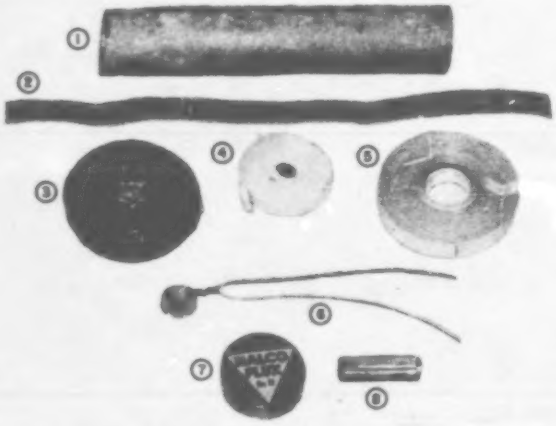


BILL OF MATERIALS FOR STRAIGHT JOINT
RUBBER-INSULATED LEAD-COVERED CABLE

ITEM	UNIT	QUANTITY (3 JOINTS)				
Code No.		1,2,3	4,5,6	7	8	9 & 10
Size of Larger Conductor (AWG or MCM)		6,3,2	2/0,4/0,350	500	750	1500 & [illegible]
Cloth Abrasive #150 1-1/2" Wide	foot	6	6	6	12	15
Compound, Filling-Plastic	pint	5	5	5	6	12
Connector, Straight or Reducing	each	3	3	3	3	3
Cord, Melrose	inch	15	15	15	15	15
Flux, Stearine	2 oz. stick	1	1	1	1	1
Pasters, Paper 2 1/2" x 12" Strips	each	9	12	12	18	24
Sleeve, Lead for Plastic Compound (I.D. x Length)	each	3(1 1/2x9)	3(2 1/2x11)	3(2 1/2x12)	3(3x13)	3(3 1/2x18)
Solder, Pig (40-60 Tin-Lead)	pound	4	6	6	9	12
Tape, Friction	roll	1	1	1	1	2
Tape, Ozone Resistant Rubber 3/4" Wide	roll	2	3	4	6	12
Wiping Rags	pound	1	1	1	1	1

65.10

Figure 11-14. — Bill of materials for lead cable splicing.



1. Lead sleeve
2. Bonding tape
3. Friction tape
4. Cotton tape
5. Tape, ozone resistant rubber
6. Splice tag
7. Flux
8. Split connector

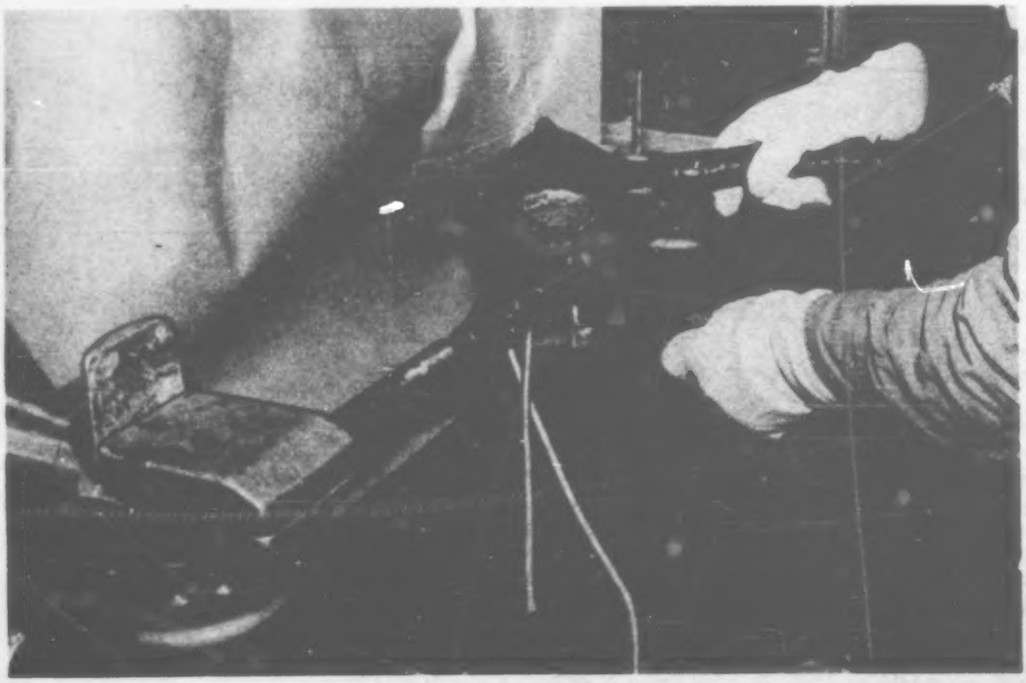
73.117

Figure 11-15.—Material for splicing conductor.

of about 1/4 in. between the end of the connector and the conductor insulation, as shown in the third step, figure 11-10. Fill this space with wrappings of cotton tape, as shown in figure 11-13, to protect the rubber insulation against the heat of the solder.

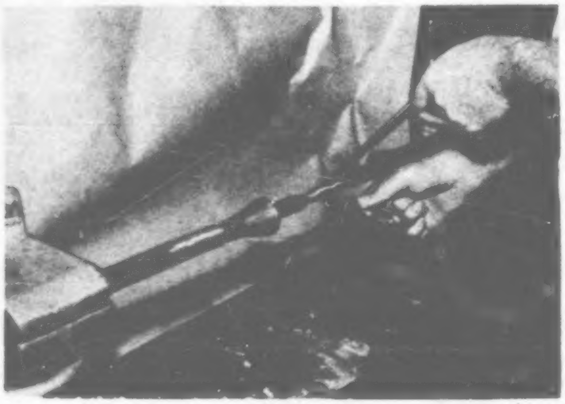
Be sure the connector is tight on the conductor ends, because there should not be any more solder inside it than is required to bond connector to conductor. Never use solder to fill space inside the connector. If a space exists, fill it with strands of copper wire. If the connector is still loose, use the crimping tool in figure 11-9 (number 12), to crimp the connector tight.

Now with two ladles (one to pour hot solder, the other to catch the drip, as shown in fig. 11-16) start pouring hot solder over the connector. Keep pouring until the connector is well heated and the solder completely penetrates the conductor and flows freely off the connector. Then make one last pour of mushy solder over the splice and lay the ladles down. Use a folded soft cloth and make a wipe from bottom to top on the back and then the front, leaving



73.119

Figure 11-16.—Soldering connector.



73.120

Figure 11-17.—Polishing connector.

a small ridge of solder over the split in the connector.

Clean the 1/4-in. space at each end of the connector, and then polish the connector using an emery cloth (fig. 11-17). The surface must have a very smooth finish, because any points or rough spots will cause a corona, which will in turn cause heating.

The connector is now sweated on, cleaned and polished. The next step is to wash away any traces of metal filings. To do this, use taping oil heated to approximately 230° F, using a portable furnace and melting pot such as those illustrated in figure 11-18 (numbers 4 and 5). Pour the hot oil over the connector, and over any bare metal which might have any metal filings or abrasive material on it.

Now take a pair of calipers and measure the diameter of the connector. The fourth step in figure 11-10 shows that there should be a MINIMUM of 5/16 in. rubber insulation on the connector. You therefore increase the connector diameter set on the calipers by twice 5/16., or 10/16 in., or 5/8 in.

You have 3 in. of rubber remaining between the sheath and the connector. This you coat with rubber bonding cement. Now start with ozone-resistant rubber tape at one end of the connector and fill the 1/4-in. space; then tape half-lap across the connector and fill the opposite 1/4-in. space. Continue back and forth, stopping each time 1/4 in. farther away from the lead sheath, until you have put on enough layers to bring the diameter of connector plus tape to that set on the calipers. Now put two layers of half-lap friction tape over the joint. The splice has now reached the stage shown in the fourth step, figure 11-10.

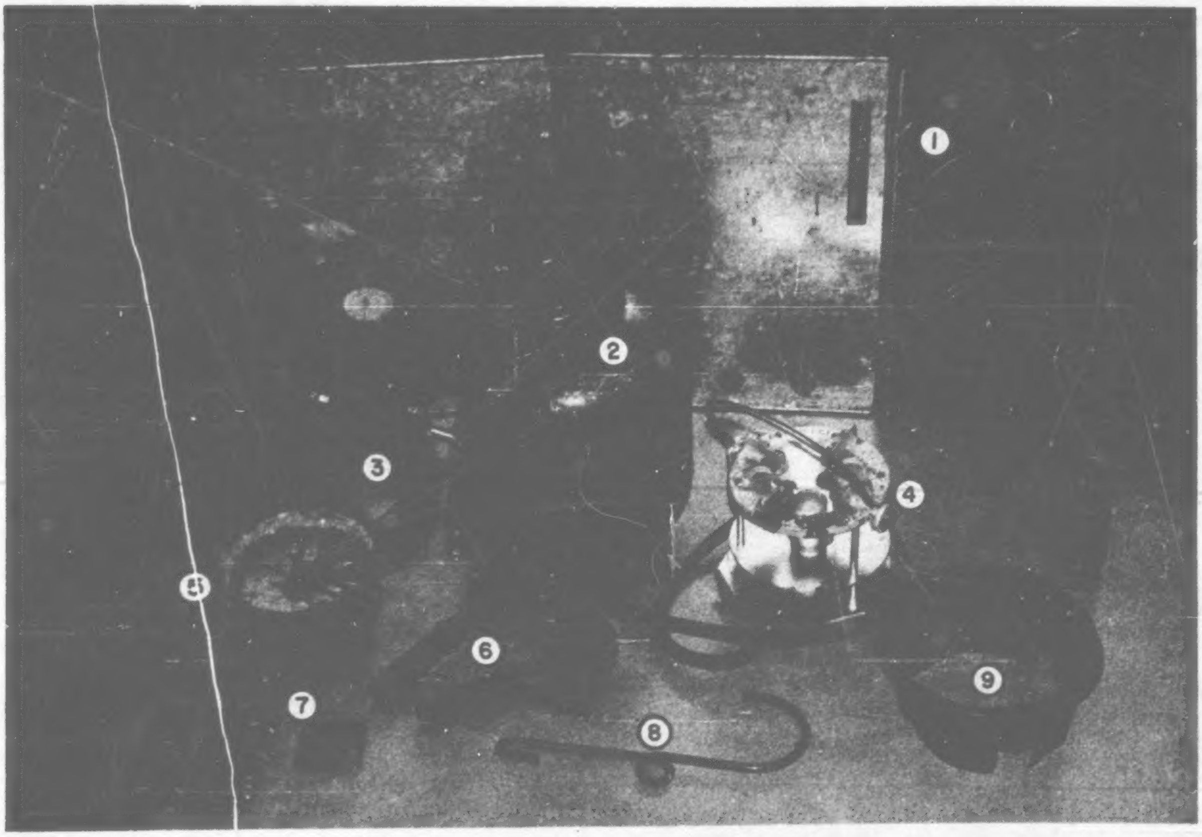
Wiping the Joint

The splice has been completed, and the next step is to wipe the sleeve to the cable and seal the joint. Most of the tools used for this are shown in figure 11-18.

Center the sleeve over the splice, and start forming the ends by rotating the sleeve and tapping lightly with a wooden dressing tool (fig. 11-19). If the bell starts getting too long, tap it lightly on the end. If it is too short, hit a few taps further back on the sleeve. Figure 11-20 shows a well-formed bell. After a little practice you will be able to control the shape quite easily.

Now you are ready to put the "pasters" on the sleeve and sheath. These are strips of gummed paper, 2 inches wide, that protect the lead sleeve and sheath from the initial heat of the wiping lead and give a smooth line to the finished wipe. On each end of the sleeve, about 1/4 in. back from the beginning of the bell, put a paster around the sleeve. Now about 1 in. from the bell of the sleeve put a paster on the cable sheath. Figure 11-21 shows pasters in place. The pasters outline the working space for the wiped joint. Take a small amount of hot lead and bond the sleeve to the sheath at one end. This bonding will prevent the sleeve from moving while you are wiping the joint at the other end.

Wiping is done in four stages: tinning, heating, rough-forming, and finish wiping. The tinning process is more or less the beginning of the heating process. Heat the wiping lead to approximately 760° F. If you do not have a thermometer, use a piece of folded brown paster paper to check for temperature as follows: Dip the paper in the lead and remove immediately. If it is scorched to the point where it appears about to ignite, the lead is hot enough to use. A 60/40 percent mixture of bar solder (60 percent lead and 40 percent tin) is the best mixture for wiping.



1. Wind shield
2. L-P tank and regulator
3. Hose and torch
4. Furnace
5. Melting pot
6. Ladles
7. Pads
8. Pot hook
9. Furnace hood

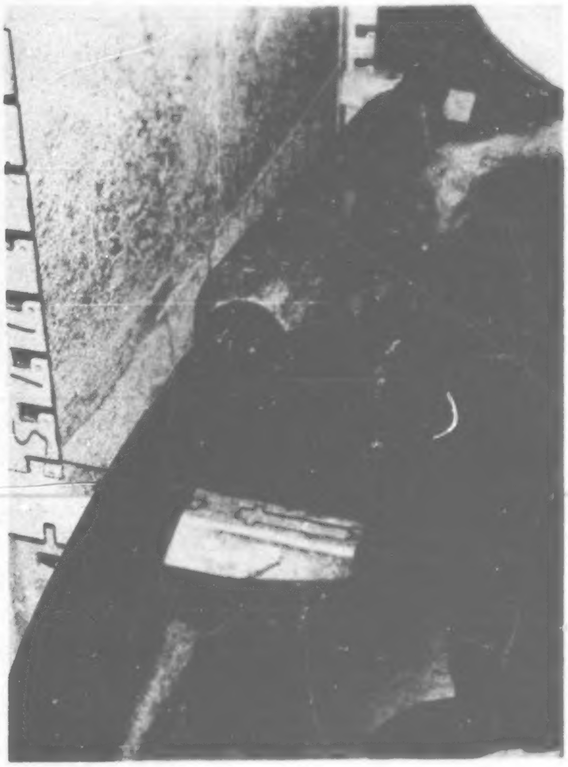
73.121

Figure 11-18.—Tools for wiping sleeve.

Pour the hot metal from a ladle onto the pasters first, and then allow it to splash over the joint until the joint is warm. By rapidly moving the ladle back and forth, the whole area can be tinned without burning the sleeve (fig. 11-22). Hold a catch cloth about 1/2 in. below the joint to keep the cool lead in the cloth from sticking to the joint. Do not bring the cloth up the sides of the joint at first, as you will have a lot of cold solder that would tear the cloth. Keep pouring in this manner until the metal flows freely over the joint and you have a good tin all over the joint.

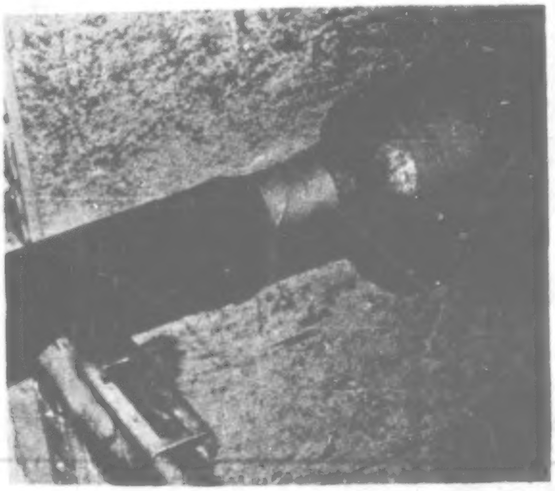
You are now ready to heat the joint. Remember, to get a good wipe, the lead in the sleeve and the sheath must be almost as hot as the wiping lead—that is, almost at the melting point. Determining the correct temperature takes practice; no book can tell you just when the joint is at the right heat to start the forming process.

You wipe the joint with a finishing cloth. Have it handy, so you can pick it up as soon as you are ready to lay down the ladle. When you think you have the joint at the right heat, and have a ladle about 3/4 full of mushy lead, pour



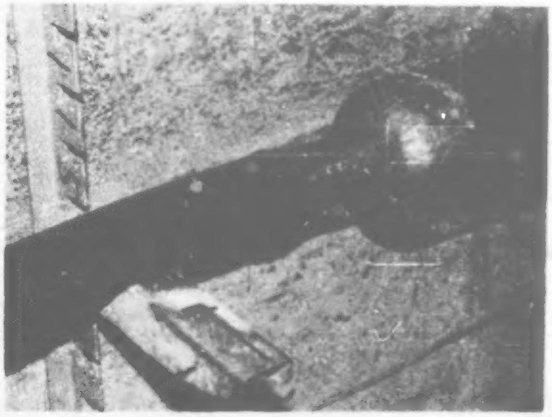
73.122A

Figure 11-19.—Forming the bell with dressing tool.



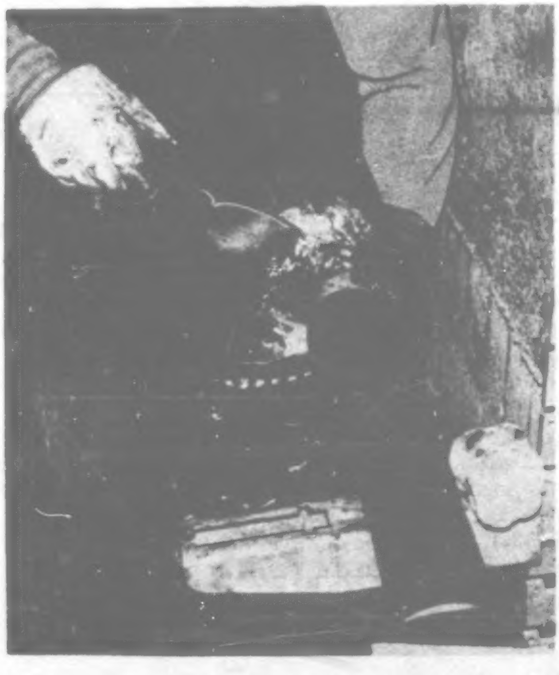
73.122C

Figure 11-21.—Sleeve with pasters in place.



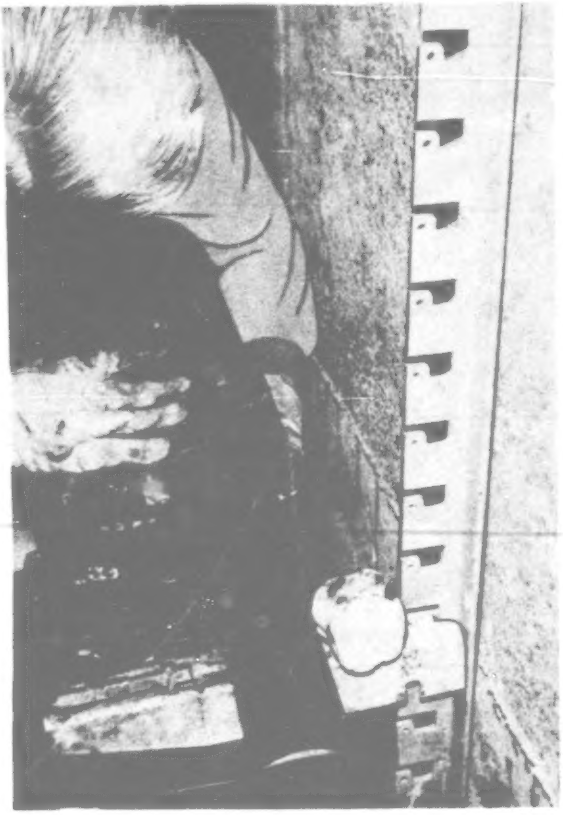
73.122B

Figure 11-20.—A well-formed bell.



73.123

Figure 11-22.—Heating the joint.



73.124

Figure 11-23.—Shaping the rough form.

the lead over the joint, lay the ladle in the drip pan, pick up a finish cloth in one hand and a catch cloth in the other, and start forming the joint. With the catch cloth under the joint, slide the finish cloth between the catch cloth and the lead. In this way you can start working the excess lead from the bottom to the top of the joint. Now with one cloth on each side (fig. 11-23) you can get a very good rough form.

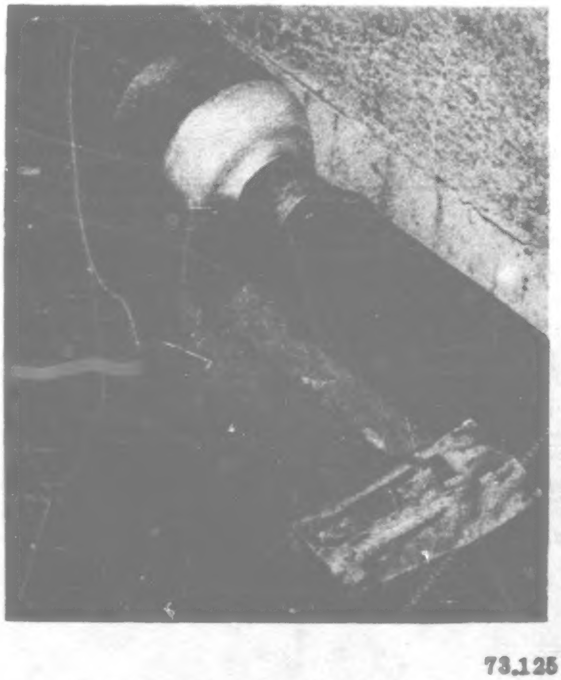
Use the finish cloth to push the lead from the pasters back onto the rough wipe. With a little practice you will be able to have a rough form in a very few movements, but remember you have to work fast and with as little handling of the lead as possible. DO NOT PAT THE LEAD IN PLACE.

Now you are ready to finish the wipe. This should be done in three movements. First, with the finish cloth in both hands (held at the top with thumbs and forefingers, and with the middle fingers along the edges of the cloth so that the cloth is cupped somewhat to the shape of the joint), start at the bottom on the back side and wipe up to the top. Now reverse the cloth, but hold it in the same way, and wipe from bottom to top on the front side. The third motion is to wipe gently lengthwise along the cable from sheath to sleeve, to remove the excess metal brought to the top. After a few trial wipes you will find this is not as hard as it sounds. Figure 11-24 shows a finished wipe.

Let the joint cool before removing the pasters, because any movement can crack the joint while the lead is still soft. After it cools, inspect for smoothness and uniformity. One common error of a beginner is to wipe too heavily on the bottom, to the extent that the joint comes out concave instead of convex below.

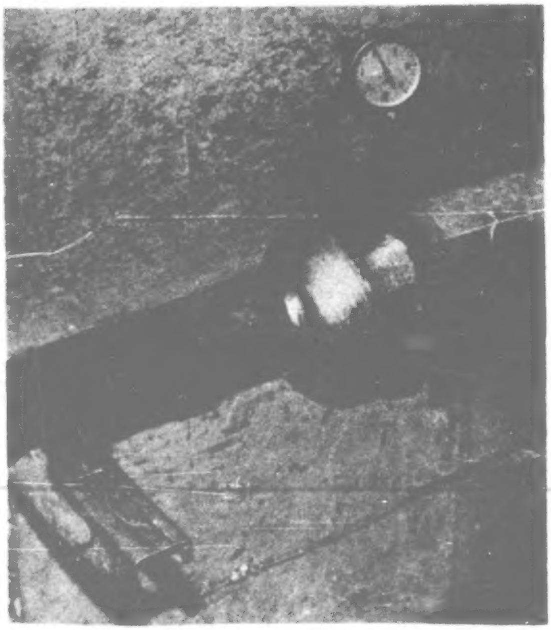
Do not attempt to smooth a wipe with a torch or hot iron. If it is not right, the only thing to do is melt the wipe off with hot lead and start all over again.

If the wipe looks all right, remove the pasters and put an air gage on for a pressure test as



73.125

Figure 11-24.—The finished wipe.



73.122D
Figure 11-25.—Making pressure test on cable splice.

shown in figure 11-25. Using a hand air pump, build up pressure to read about 6 psi on the gage. If the joint holds the pressure for about 15 minutes, you can assume it is tight and remove the gage.

Filling With Compound

You are now ready to fill the joint with compound. If the sleeve does not have filling plugs like those shown in step 5, figure 11-10, cut a filling slot in the end opposite the pressure gage. Cut this slot in the shape of a crescent, and bend back the flap (see fig. 11-26). The quarter-inch punctured hole made by the pressure gage can, after the gage is extracted, serve as a vent hole while the compound is being poured in.

Heat the compound in a kettle to a temperature between 275° F and 300° F. DO NOT HEAT THE COMPOUND IN THE CAN OR CONTAINER IN WHICH IT WAS RECEIVED. Pour it in as shown in figure 11-27, until it overflows the vent hole and the slot.

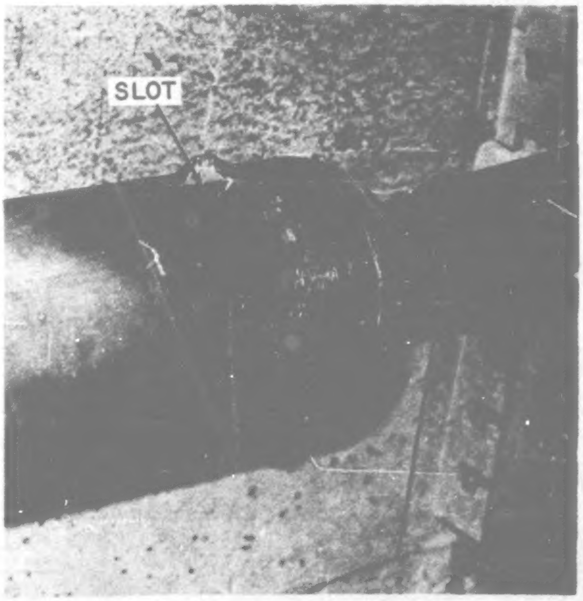
When the compound has cooled, bend the flap down and close up the vent hole as much as possible. Then put pasters around the hole 1/4 in. from the cut, and solder with the soldering iron.

Cable Splices for Higher Voltages

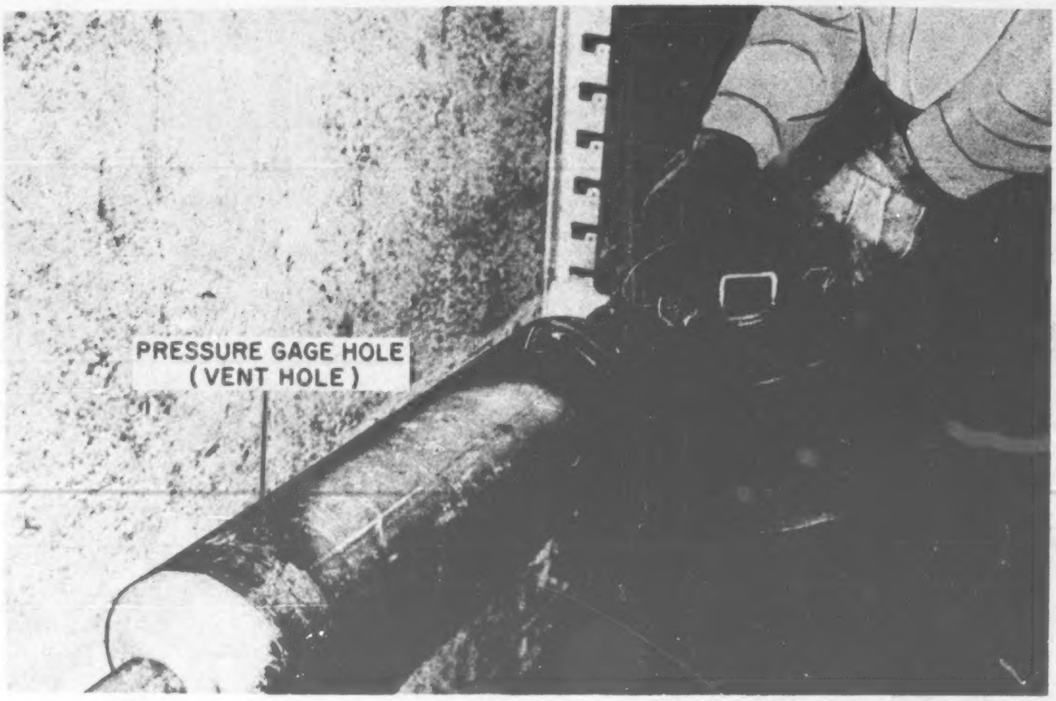
For voltages from 5 kv to 15 kv the splicing procedure is about the same as that previously described, except that there is the additional step of boiling out the joint after the splice is completely taped. For insulating splices in this 5 kv to 15 kv range, varnished-cloth tape is used.

The oil used for boiling out is taping oil, heated to approximately 230° F. Boiling out consists of pouring the hot oil over the joint, to drive out any moisture caused by damp air or by moisture on the hands.

The varnished cloth tape used for these higher-voltage splices is soaked in taping oil, and a layer of oil is put on the joint after each layer of tape. The pressure applied with each layer of tape forces out, with the excess oil,

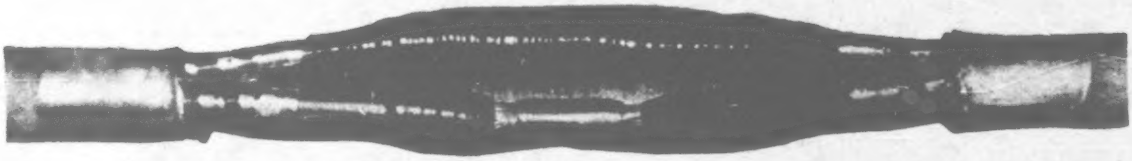


73.122E
Figure 11-26.—Slot for pouring compound.



73.126

Figure 11-27.—Pouring compound.



73.127

Figure 11-28.—Three-conductor 15-kv joint partly taped.

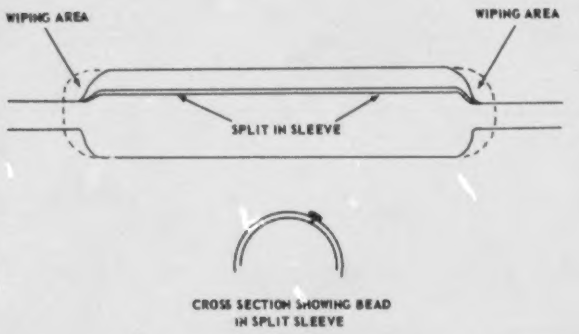
any air bubbles which might be under the tape. Figure 11-28 shows a three-conductor 15-kv joint partly taped.

Split-Sleeve Connection

In the cable splice previously described the sleeve was slid over the end of a conductor and pushed back out of the way. Sometimes the space for pushing back doesn't exist, in which case a sleeve must be split, opened out, and applied directly to the place it will finally occupy.

For this process you make up the joint and tape it for the sleeve as previously described, but without sliding the sleeve first onto the cable. You form the bell on each end of the sleeve as previously described. Next, however, you split the sleeve lengthwise with a saw, and spread it open wide enough to go around the joint, being careful not to twist it out of shape (see fig. 11-29).

Clean a space 1 in. wide on each side of the split for the entire length of the sleeve. Use



73.128

Figure 11-29.—Split sleeve.

a piece of rope to form a slack loop around the sleeve. Insert a toggle, such as a hammer handle, in the loop, and wind the loop tight enough to close the split sleeve up around the joint. Tack the two sides together with solder, to hold the sleeve closed.

Next put a paster on each side of the split, lengthwise, about 3/4 in. from the split, and one at each end. Use a hot soldering iron to melt stearine over the space between the pasters. With the soldering iron, melt a small amount of 50-50 bar solder along the split. Then use the iron to spread the solder over the area, to give the exposed surface a good tin.

Again using the soldering iron, run a heavy bead of solder the length of the seam. With a hot iron held at a slight angle, and one continuous movement, run a bead down one side of the seam, tapering from the edge of the paster to about 1/4 in. thick at the center. Move to the other side and repeat the process. When finished, you should have a smooth bead along the seam, from a feather-edge on the outside to 1/4 in. thick at the center. Then proceed to make the end wipes, air-pressure test, and compound filling of the splice as previously described.

SPLICING WITH MOLDS

Anytime that you make a splice, you will have a print (a sheet of instructions) which comes with the material. It usually is labeled "Recommended Procedures." Some linemen make the mistake of believing that a print is unnecessary; they throw it away and haphazardly make the splice. Then they blame the material if the splice is faulty. Follow the printed instructions step by step for serviceable cable splices. You may use the materials from one of several manufacturers. But the process of making the splice will be similar, regardless of which brand you use. The first step is to prepare the ends to be joined. Assume that a splice is to be made in a single-conductor cable with either neoprene or rubber insulation.

Preparation

First measure the connector sleeve from one end to the center indention. Add 1/2 inch to the measurement as allowance for expansion of the connector, and mark this distance from the end of the conductor. Shave off the insulation between the mark and the end of the conductor. Be careful not to cut or nick the wire as you remove the last of the insulation. Next, pencil the insulation to make a slope of about 45° from the end. If you are going to finish the splice with a kit using a resin or similar compound, be sure to check the length of the mold. Kit instructions direct that a cable sheath be trimmed a specified distance so that the mold will cover at least an inch of the sheath on each end. Remove the cable sheath as required. Check the conductor to see that the end is cut square, to make a good electrical connection. A conductor which was cut with a hacksaw should not be any problem. However, conductors which were cut with a tool such as a cable cutter will have been distorted. The metal will have been compressed out of shape so that there is a bulge. This bulge must be eliminated by trimming it off with a file before the conductor will slide into the connector sleeve. The mold from the splicing kit must have the ends trimmed to fit the cable. To determine the trim point, insert the cable into the mold and cut off the mold at the point where the cable stops. Slip the mold over one of the cables before the conductors are spliced. Only a split mold can be installed after conductors are joined.

Connecting the Conductors

Use a compression sleeve of the proper size and material for the conductors being joined. Slide the connector over one conductor so that the end butts against the center indentation. Using a compression tool with the correct size die, make the first press next to the center. The edge of the die should overlap the center line.

To make the next press, the edge of the die should just overlap the previous press. Continue working to the end of the sleeve in this manner. Next, insert the second conductor in the sleeve until it butts against the center. The press this side the same way, working from the center of the sleeve to the end. Tape the splice with insulating tape if required for the voltage carried by the cable.

Pouring the Compound

Center the mold over the splice and seal the ends with material provided in the kit. Wrap with tape to complete the seals and hold the mold in place on the cable. Mix the compound according to directions for the pack you are using. In cold weather, the bag of compound should be warmed to about 70° F before mixing is started. As soon as the compound is mixed (about 2 minutes), pour compound into the mold at the pouring spout. Tilt the mold slightly to eliminate trapped air. The compound acts very rapidly, so you must complete pouring with no delay.

As soon as the splice is completed, the cable should be tied securely in its permanent position with tying material approved for the cable. As an example, a cable with a lead sheath should be secured with lead tie wire. The cable can be placed in service as soon as the compound sets, which may take about 20 minutes. However, it is customary on a new cable first to make a megger test for insulation resistance and then to measure the conductor's resistance with a Wheatstone bridge. After testing, the cable may be placed in service. The cable should have a tag attached to it in a prominent place at each manhole and at both terminations. The cable tag should identify the cable by letter and/or number and should also tell the voltage at which the cable operates.

A lateral cable is similar to a service drop, except that it is underground. The cable is installed by pulling it into a duct as already described. Because a lateral is connected to an existing cable, you need to make a tee-connection splice. There are a few differences between a tee and a conventional splice. First, you need a kit with a special mold body to accommodate the tee. Next, the conductor you tap is not cut; just clean the sheath and remove the insulation for the distance required as directed by the instructions in the kit. Then, prepare the end of the lateral conductor as you would for a splice. Attach the lateral to the tapped cable with approved connectors. Be sure that the cables have enough slack so that there will be no strain on the tee. Last of all, position the mold body and fill with compound, according to the instructions for the kit you are using.

TAPECAST SPLICE

The first step in making a tapecast splice is to be sure that you have scraped the cable so that all dirt, wax, and cable pulling compounds are removed. You must do this so the resin will bond and make a moisture-tight seal. Follow the manufacturer's instructions as you remove the cable jacket and nonmetallic filler tape from the ends which you plan to splice. You ring-cut the jacket at the designated places. Be careful not to cut into the metallic shielding; unwrap it from the cable. Leave about 1 in. of the shielding exposed on each end of the cable where you have removed the jacket. Tack the metallic shielding in place with solder so that it will not unwind from around the cable.

Any time that you must solder during the making of a splice, be careful not to overheat the insulation. Later, as you wrap electrical shielding tape and use the last of one roll to which you must connect another piece, hold the two pieces away from the cable splice. Place a drop of solder on the soldering iron. Then put the iron uder the overlapped pieces of electrical shielding. Apply solder on top of the shielding over the drop of solder which you left on the iron.

You will solder a ground strap into the cable shielding if you plan to use one. Use a ground strap having the same amperage capacity as the cable metallic shielding. Next, remove the semiconducting material. Leave the designated amount (approximately 1/2 inch) exposed inside the two pieces of cable metallic shielding which you previously left exposed. Clean all of this material from the cable insulation. Use a knife, rasp, or nonconductive abrasive cloth. Be careful that you do not cut into the cable insulation.

Being careful not to nick the conductors, remove the cable insulation from the end of the conductors for the right distance (approximately 1/2 inch plus 1/2 the length of the connector). Follow the instruction measurement as you pencil the insulation at each end. Buff the tapers so that no voids remain after the joint is insulated.

Taper the cable jacket at each end smoothly and buff the taper. Finish the preparation by using a lint-free, clean cloth to clean the entire splice area. After preparing the cable, you are ready to connect the conductors.

Follow the manfacturer's directions as you use a connector to join conductors. If you are joining copper and aluminum conductors, you must use a special connector, or the two dissimilar metals will set up an electrolysis. Use a hydraulic press or crimping tool to cause the connector to make the connection. After you have the cables correctly connected, fill the connector indents with a semiconducting tape. When you use a hydraulic press or crimping tool, it leaves indents or voids in the connector. Penciling cable may also leave a void. Any void or high point tends to make electrical stress points. These points act as paths to ground. If you fill these voids and indents with semiconducting tape, there is a smooth flow of energy with no buildups. You wrap the tape over the exposed conductor and connector area, and overlap the cable insulation. Use a half-lap so that the tape will lay uniformly throughout the splice.

Next, wrap high-voltage splicing tape over the semiconducting tape and over the exposed insulation according to the manufacturer's directions. Taper the outside gradually, making the greatest diameter over the penciled insulation. Always try to half-lap when taping; this produces a uniform buildup. Also hold the tape so that it does not slant but goes straight around the cable. When it slants, voids or holes are sometimes left in the tape on the underside of the splice. Also, when you stretch the tape, you do not in any way change the tape's physical or electrical qualities. Thus, if you stretch the tape in the connector area and at the splice ends, you reduce voids.

After using the splicing tape, wrap one layer (half-lapped) of semiconducting tape over it and follow this by wrapping the splice with one layer (half-lapped) of electrical shielding tape. Overlap this onto the cable metallic shielding at each end and solder the ends of the shielding. Then cover the entire area of shielding braid with one layer (half-lapped) of plastic electrical tape. If you stretch the tape as you work, it flattens and holds the shielding braid.

Next, attach a bonding or ground wire. If the splice becomes defective, the ground wire provides a path to ground, thus preventing the electricity from traveling further down the conductor and causing a fault where it would be harder to correct. Shape this ground wire close to the tape and solder it to the metallic shielding at each end, being careful not to overheat the insulation. This provides continuity from the shielding on the other side of the splice. Use a wire which has the same amperage capacity as the shield. Next, apply the resin overcast sheath.

Wrap the entire splice with spacer tape. Extend it into the cable jacket approximately 3 inches. Start wrapping in the areas which have smaller diameters and build up to the thickness given in the manufacturer's directions, approximately 1/4 to 3/8 inch. Place an injection fitting in position according to the instruction sheet. Tape this into place with electrical tape by taping from the center of the fitting over the spacer tape and onto the cable jacket. Form a liquidtight seal. Wrap the entire splice with the electrical tape. Cover this with two half-lapped layers of restricting tape.

Because you have trapped air in the splice, you will need to vent the splice so that as the resin goes in, it can force the air out. Be careful that you do not puncture the cable jacket as you vent the splice.

Follow the manufacturer's directions closely as you mix the resin. When you have mixed the resin, clear one corner of the container or clear the center top by pushing the resin down into the lower part of the container. Tape-patch the piercing nozzle firmly onto the empty corner or top of the container. Then load the resin pressure gun. Put the tip of the nozzle through the hole in the gun cap and lock the cap in place. Then pull the nozzle through the cap and lock it to the cap by twisting slightly. Connect the nozzle to the injection fitting on the splice by rotating the gun itself so that you will not damage the resin container. When you have it connected, you start working the gun handles. This pierces the container and resin begins to flow into the splice. Inject the resin slowly. Let the resin run out of the vent until there is no longer any air escaping. Then wipe the resin off the tape and close the vent by taping it. The resin sets quickly. If the splice takes more than one container of resin, someone should be mixing the resin in one container while you inject the resin which is in the gun. When you empty the container, be sure to release the pressure on the gun so that the valve in the injection fitting can seat and prevent the resin from backing out of the fitting. Remove the gun by rotating the entire gun.

When you have removed the gun, take the cap off it, remove the empty resin container, and reload the gun with another container of resin. Continue injecting resin until the splice is full; that is, until the vent shows that the splice is filled by spilling resin. Remove any resin that has spilled before it hardens. Soap and water will remove the resin from your hands. Do not move the cables with the splice until the resin has hardened. When it has hardened, you can remove the restricting tape.

RESIN SPLICE

In making a resin splice, you prepare the cable in the same manner as for the tapecast splice except that you do not taper the cable jacket at each end. You connect the conductors in the same manner by joining them with a connector and crimping according to the manufacturer's directions, and by filling the indents with semiconducting tape. Then you apply one layer of semiconducting tape, half-lapped, over the cable semiconduction material and onto each end of the cable metallic shielding. The rest of the procedure is different because the makeup of this splice is primarily resin as its name implies.

You wrap the recommended amount of spacer tape over the semiconducting tape and the cable insulation almost to the cable semiconducting material. Start with the indents and level-wind the spacer tape across the joint. Do not stretch the spacer tape. Wrap shielding tape (quarter-lapped) over the spacer tape and overlap the cable metallic shielding at each end. Solder the ends of the shielding tape to the cable metallic shielding, being careful not to overheat the insulation. Attach the correct size bonding wire (usually No. 6 AWG is adequate) and solder it to the cable metallic shielding at each end. Shape the wire closely against the splice. Again level-wind spacer tape over the entire joint to the designated thickness, tapering it at each end. The rest of the procedure is the same as that for the tapecast splice.

Using the same method that you used for the tapecast splice, you install the injection fitting, vent the splice and cover it with restricting tape, mix the resin, load the resin pressure gun, and inject the resin. The resin type of splice requires much more resin than the tapecast type.

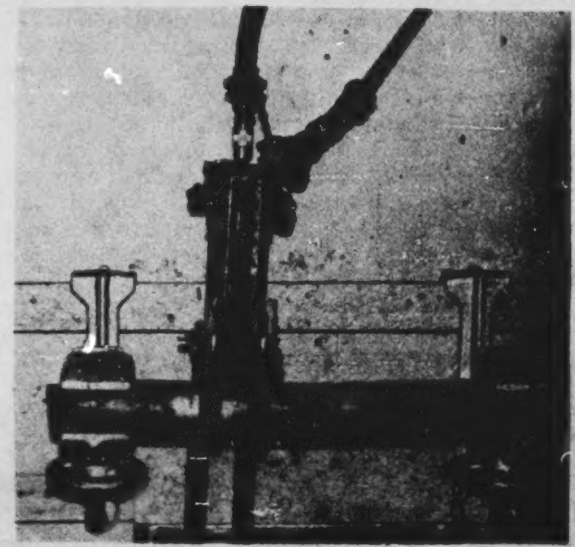
SAFETY

Strict adherence to safe practices is mandatory. There are three major areas of consideration in underground power distribution: (1) testing for live cable, (2) safety in and around manholes, and (3) handling of hot liquids.

TESTING FOR LIVE CABLE

Before working on a cable that has been in service, make sure that it is dead. The shorting tool shown in figure 11-30 is used for this purpose. To use the shorting tool, also known as a "lifesaver," fasten it onto the cable at the point where it is to be cut for splicing. Lead the hose to a hydraulic pump outside the manhole. Be sure no one is in the manhole when you make the test.

As you work the hydraulic pump outside the manhole, the shorting tool drives a plunger into the cable, shorting out all the conductors. If the cable is live, there will be a terrific flash, which will give you an idea of what would have happened to you if you had cut the cable with a hacksaw without prior testing.



73.112

Figure 11-30.—Lead cable shorting tool.

MANHOLES

In working in or around manholes, always ensure your own safety and that of others by first checking the ventilation. Proper safety precautions require that a gas test be made by qualified personnel before a manhole is entered. If gas is detected, the manhole must be ventilated with a power blower, and it may be necessary to reventilate periodically to maintain a safe working atmosphere. If men working below are not visible to men on the surface, someone above ground should check frequently to ensure that all is well with the men below.

When manholes are located in the vicinity of gasoline storage tanks, the check on ventilation must be extra thorough, because of the additional danger of gasoline leakage and fumes.

It goes without saying that an open flame should never be taken into or near a manhole in which explosive gases may be present.

Never use an acetylene torch underground, or even near the end of a pipe or conduit leading underground. A mixture of 3 percent acetylene with 97 percent air is explosive in a confined space. Maximum explosive effect is reached with a mixture of 7.7 percent gas and 92.3 percent air.

When you work in a manhole or other excavation, you should always make sure that it is protected by some sort of barrier or guard. Any opening that must be left open overnight should be barricaded and provided with warning lights.

Use the safety harness if you are going to work in a manhole where gas may be present. This harness is equipped with about 25 ft of manila line, fastened to a ring at the back. It is so designed as to make it possible for an unconscious man to be hauled up in nearly erect position.

HOT LIQUIDS

To avoid spillage, do not move hot liquid if its level is within 2 inches of the top of the container. Adjust to the correct level. When you carry it, your shoe soles must be clean and dry, and you should walk with a sliding or shuffling movement.

Always wear high shoes when handling hot liquids, such as melted lead. Always wear goggles when pouring melted lead, hot oil, or wiping solder. Never use leather-palm gloves when wiping lead. A leather palm glove will transfer the heat from the lead. A cotton glove won't. Always use plain cotton gloves with knitted wristlets.

In working with sealing and insulating compounds, be careful to observe the manufacturer's instructions as to temperatures. Heat slowly at first; you can increase the amount of heat later. Avoid makeshift containers for heating; always use a regulation explosion-proof kettle.

The use of a safety can for fueling furnaces reduces fire hazards. One of these cans is equipped with a pressure-release valve, so that extreme heat will not cause it to rupture.

When soldering joints, or tinning conductors, make sure that the furnace is far enough away from the manhole that no hot metal can spill into the manhole.

Using a wet or a cold ladle will cause hot compound or molten metal to spatter.

AIRFIELD LIGHTING

Airfield lighting refers to systems of illuminated visual signals provided to assist pilots in the safe, efficient landing operation of aircraft at night and during periods of restricted visibility. Airfield lighting is standardized and includes runway, approach, taxiway, and obstruction and hazard lighting, plus beacons, lighted wind direction indicators, and special signal lights. Not all these items are included in advanced base airfields. All lighting, however, except certain obstruction lighting is normally controlled from the control tower. The lighting system includes all control devices, switching gear, regulators, transformers, and all accessories necessary to produce a working facility.

STANDARDIZATION

The configuration, colors, and spacing of runway, approach, and taxiway lighting systems are uniform, regardless of anticipated length of service, mission, or method of installation. The basic color code is as follows:

Blue—taxiway lighting
Clear (white)—the sides of a usable landing area
Green—the ends of a usable landing area (threshold lights)
Red—hazard, obstruction, and non-landable area
Yellow—caution

APPROACH LIGHTING

An approach lighting system presents a configuration of lights which provide extended visual guidance toward the centerline of a runway (fig. 11-31). At airports with primary instrument approaches, the system extends 3000 ft outward from the threshold of the usable landing area. For other than primary instrument approaches, the approach lighting system extends outward only 1500 ft. Directional guidance is provided by barrettes, a crossbar, and sequential flashing lights (fig. 11-32).

Barrettes

The barrettes, or centerline bars, are composed of five spaced incandescent lights. These may be mounted flush with the runways or as shown in figure 11-33, depending upon their required elevation.

Crossbar

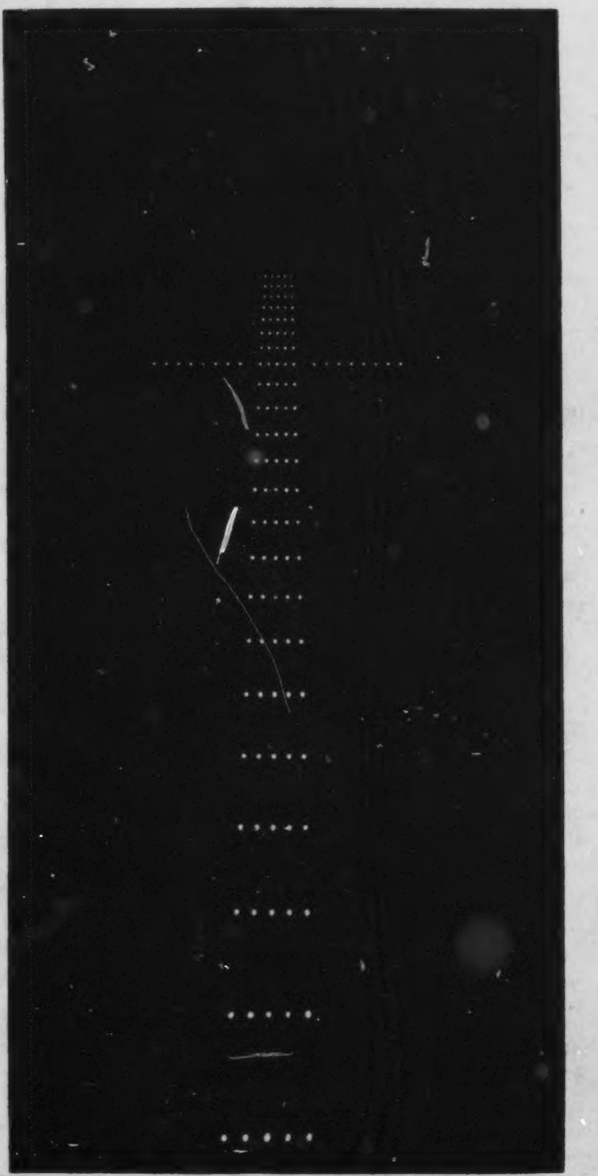
White crossbar lights (fig. 11-32) provide an unmistakable definite distance indication to the pilot. The bar is placed 1000 ft outward from the green threshold lights, and is approximately 100 ft in length.

Sequential Lighting

Immediate identification of the system and possible earlier view are provided by the use of sequenced flashing blue-white lights of high peak intensity. No two units flash simultaneously. Each unit is precisely timed by means of cams on a rotating shaft to flash one after another, beginning with the outermost unit and continuing to the innermost unit. Each cycle takes one-half second and repeats continuously. The resulting effect is one of a light moving at a rapid pace toward the runway. There is no appreciable pause between the innermost flash and the beginning of the next sequence. Mounting is shown in figure 11-33.

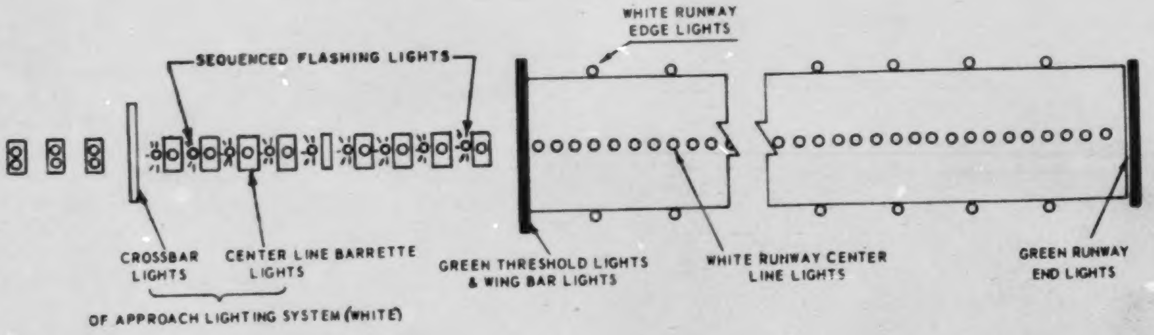
Runway Lighting

This is the principal element of airfield lighting. It provides the standard pattern of lights outlining the runway to clearly indicate side and end limits (fig. 11-32). Side limits are marked by two parallel rows of white lights, one row on each side of, and equidistant from, the runway centerline. The spacing of the lights



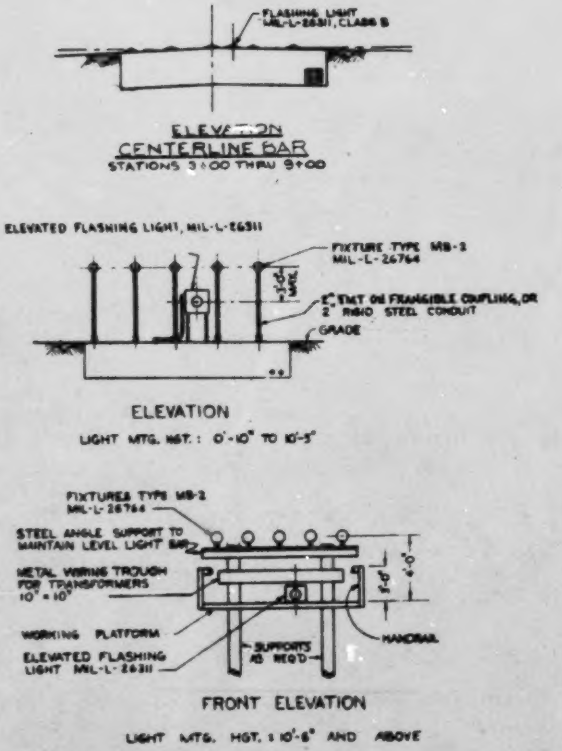
73.326

Figure 11-31. — Approach lights in foreground.


WHITE RUNWAY EDGE LIGHTS
SEQUENCED FLASHING LIGHTS
CROSSBAR LIGHTS
CENTER LINE BARRETTE LIGHTS
OF APPROACH LIGHTING SYSTEM (WHITE)
GREEN THRESHOLD LIGHTS & WING BAR LIGHTS
WHITE RUNWAY CENTER LINE LIGHTS
GREEN RUNWAY END LIGHTS

73.327

Figure 11-32.—Lights visible to an airplane moving from left to right.


FLASHING LIGHT MIL-L-26311, CLASS B
ELEVATION
CENTERLINE BAR
STATIONS 3+00 THRU 9+00
ELEVATED FLASHING LIGHT, MIL-L-26311
FIXTURE TYPE MB-2 MIL-L-26764
1'-0" MAX.
2" EMT ON FRANGIBLE COUPLING, OR 2" RIGID STEEL CONDUIT
GRADE
ELEVATION
LIGHT MTG. HGT. : 0'-10" TO 10'-5"
FIXTURES TYPE MB-2 MIL-L-26764
STEEL ANGLE SUPPORT TO MAINTAIN LEVEL LIGHT BAR
METAL WIRING TROUGH FOR TRANSFORMERS 10" x 10"
WORKING PLATFORM
ELEVATED FLASHING LIGHT MIL-L-26311
SUPPORTS AS REQ'D
HANDRAIL
4'-0"
6'-0"
FRONT ELEVATION
LIGHT MTG. HGT. : 10'-6" AND ABOVE

73.329

Figure 11-33.—Centerline bar and sequential flashing mounting.

within the rows is uniform, and the rows extend the entire length of the runway. End limits are outlined by runway threshold lights, which are green and visible from all sides and vertical angles. Runway threshold lights are spaced along the threshold line, which is 0 to 10 feet from the end of the runway, and perpendicular to the extended centerline of the runway. A runway edge fixture and handhole installation schematic is shown in figure 11-34.

Figure 11-35 shows the plan for runway centerline lighting together with a representative wiring diagram.

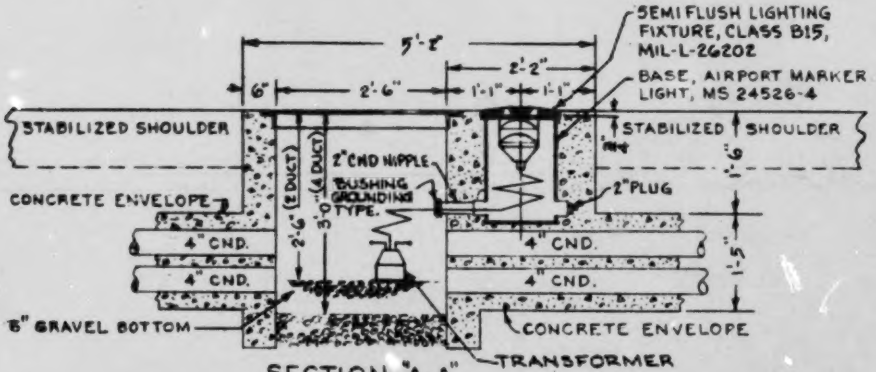
On occasion, certain airports require narrow gage runway lighting. A representative wiring diagram and installation in asphalt concrete is shown for this type of lighting in figure 11-36.

Expedient Lighting

You must be resourceful when equipment is not available from the regular supply sources. Lanterns, smudge pots, vehicle headlights, or reflectors may be used to distinguish runway edges. Use of a searchlight pointed directly into the air sometimes is used as a substitute for beacon lights.

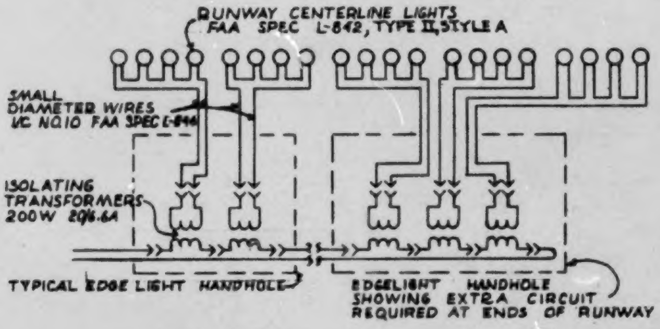
MAINTENANCE OF MARKING, LIGHTING, AND RELATED ELECTRICAL FACILITIES

Visual inspection of the airfield lighting system should be made periodically, taking into account the recommendations of component manufacturers, weather, location of the airport, numbers and nature of operations, and system complexity. In addition, regular readings should be made

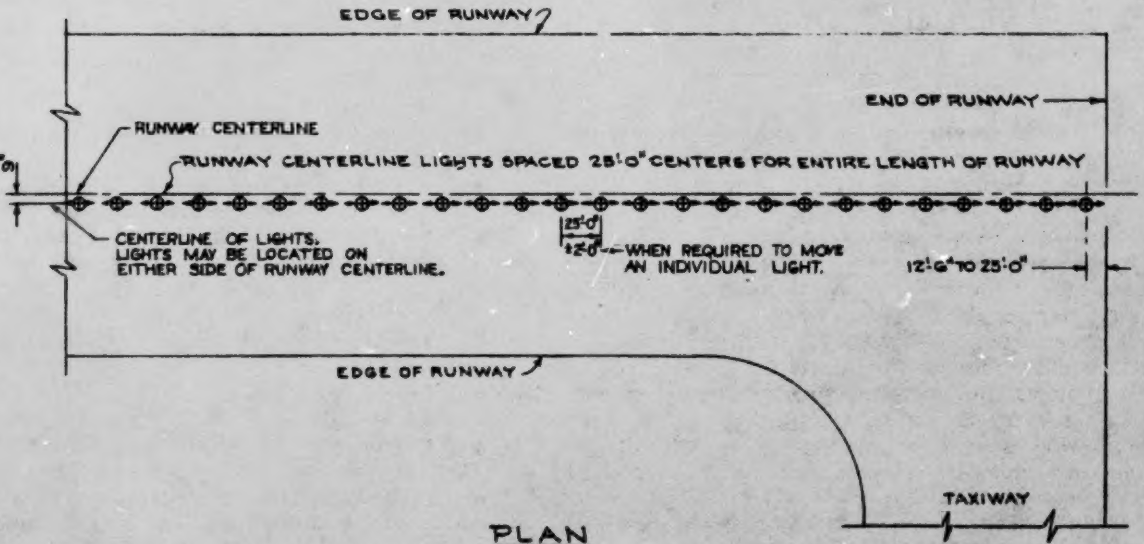

SEMI FLUSH LIGHTING FIXTURE, CLASS B15, MIL-L-26202
5'-2"
2'-2"
6"
2'-6"
1'-1"
1'-1"
BASE, AIRPORT MARKER LIGHT, MS 24526-4
STABILIZED SHOULDER
STABILIZED SHOULDER
1'-6"
2'-6" (2 DUCT)
3'-0" (4 DUCT)
2" CND NIPPLE
BUSHING GROUNDING TYPE.
2" PLUG
CONCRETE ENVELOPE
4" CND.
4" CND.
4" CND.
4" CND.
1'-5"
6" GRAVEL BOTTOM
CONCRETE ENVELOPE
TRANSFORMER

SECTION "A-A"

Figure 11-34. — Runway edge light fixture and handhole installation in runway shoulder. 73.331

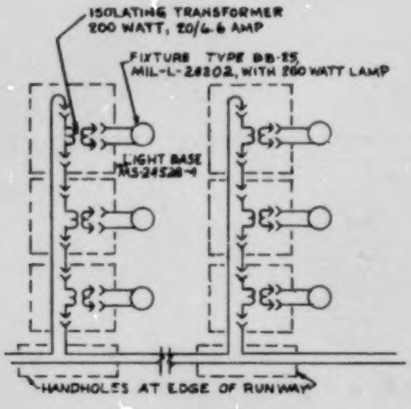

RUNWAY CENTERLINE LIGHTS FAA SPEC L-842, TYPE II, STYLE A
SMALL DIAMETER WIRES UC NO.10 FAA SPEC L-844
ISOLATING TRANSFORMERS 200W 20/6.6A
TYPICAL EDGE LIGHT HANDHOLE
EDGELIGHT HANDHOLE SHOWING EXTRA CIRCUIT REQUIRED AT ENDS OF RUNWAY

WIRING DIAGRAM

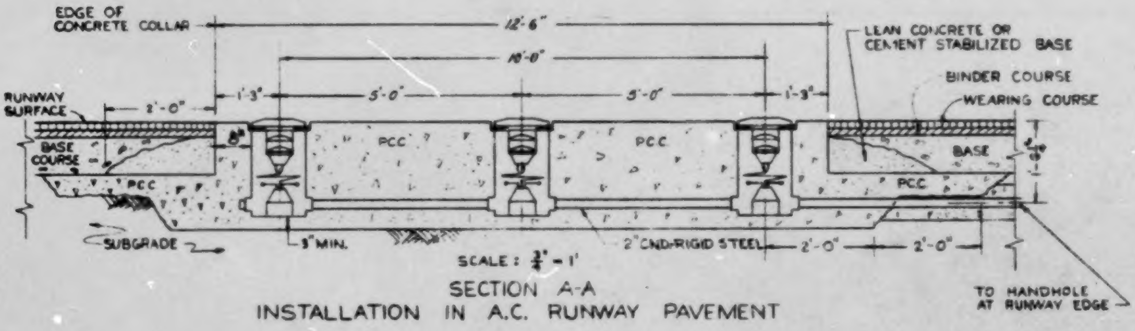

EDGE OF RUNWAY
END OF RUNWAY
RUNWAY CENTERLINE
RUNWAY CENTERLINE LIGHTS SPACED 25'-0" CENTERS FOR ENTIRE LENGTH OF RUNWAY
6"
CENTERLINE OF LIGHTS. LIGHTS MAY BE LOCATED ON EITHER SIDE OF RUNWAY CENTERLINE.
25'-0"
±2'-0" — WHEN REQUIRED TO MOVE AN INDIVIDUAL LIGHT.
12'-6" TO 25'-0"
EDGE OF RUNWAY
TAXIWAY

PLAN

Figure 11-35. — Runway centerline lighting. 73.332


ISOLATING TRANSFORMER
200 WATT, 20/6.6 AMP
FIXTURE TYPE BB-25, MIL-L-26202, WITH 200 WATT LAMP
LIGHT BASE
HANDHOLES AT EDGE OF RUNWAY

WIRING DIAGRAM


EDGE OF CONCRETE COLLAR
12'-6"
10'-0"
LEAN CONCRETE OR CEMENT STABILIZED BASE
BINDER COURSE
WEARING COURSE
RUNWAY SURFACE
2'-0"
1'-3"
5'-0"
5'-0"
1'-3"
8"
BASE COURSE
PCC
PCC
PCC
BASE
PCC
PCC
SUBGRADE
3" MIN.
2" CND-RIGID STEEL
2'-0"
2'-0"
SCALE: ¾" = 1'
TO HANDHOLE AT RUNWAY EDGE

SECTION A-A
INSTALLATION IN A.C. RUNWAY PAVEMENT

73.333

Figure 11-36.—Narrow gage runway lighting installation.

on system resistance, and other circuit tests should be made as recommended by manufacturers. Standby units should be run at regular intervals to assure readiness, if required.

Complete visual inspection of the lighting system should be made routinely at least once a week. If severe storms occur in intervening periods, resulting in excessive rainfall or lightning strikes, additional inspections should be conducted immediately thereafter. Operations of snowplows can be damaging to light fixtures, and inspections of light units should be made following such plowing operations. Circuit resistance measurements should be taken at least once each month.

As you proceed with your inspection and maintenance routines, you should look for

- Burned-out bulbs and lamps
- Broken lenses or filters
- Dirty lenses
- Vegetation obscuring lights
- Fixtures knocked over or displaced
- Damaged or insecure cones
- Evidence of lightning strikes
- Decreasing circuit resistance
- Faulty ground connections

- Malfunctioning regulators
- Water in below grade fixtures or components
- Readiness of standby power source
- Torn or damaged wind indicator
- Faded or obscure markings

When you check the circuit resistance with a megger, BE SURE TO SWITCH THE POWER TO THE REGULATOR OFF. Then you may disconnect the series cable leads at the regulator and take your resistance measurements. If you have taken periodic megger readings, you will be provided with a forecast of potential problems which will permit correction before system failure occurs.

CHAPTER 12

COMMUNICATIONS SYSTEM

In this chapter, we will discuss fundamentals of telephone communication, interoffice communication, and public address systems so that you will have a clear understanding of these systems and how to install and maintain them efficiently. Careful study of this material should enable you to do the following:

- describe a basic telephone communication system;
- operate a variety of advanced base telephone equipment;
- discuss electrical theory and planning features of telephone line construction;
- identify components of telephone switchboards and state the purpose of each;
- install, repair and maintain a telephone system;
- install and maintain a public address and interoffice communication system.

BASIC TELEPHONE SYSTEM COMPONENTS

A telephone system consists of many telephones connected together by a maze of wires. You can understand the system better, however, if you reduce it in your imagination to a single circuit connecting two telephones. This circuit consists of the following components:

1. A transmitter and receiver at each of the two locations. (You use the transmitter to transmit—that is, to send out—your voice message. You use the receiver to receive the voice message sent out by the transmitter at the other end of the line.)
2. A means of signaling—that is, activating the signal device in the subset so that the called party knows someone is calling him.
3. A source of electrical energy, required to impel the signals over long stretches of wire.
4. The wiring circuit connecting the phones and carrying the electrical energy.

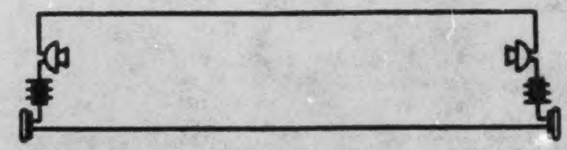
In telephone lineman's technical terminology, a telephone is called a subset, and the place where a subset is located is called a substation. The wiring system connecting the subsets is called the outside plant.

HOW THE TELEPHONE WORKS

Figure 12-1 is a wiring diagram of a basic telephone circuit. You can see that this is a series circuit from the fact that the current travels from the negative terminal of one battery back to the positive terminal of the other. A battery is the source of electrical energy which provides a constant voltage.

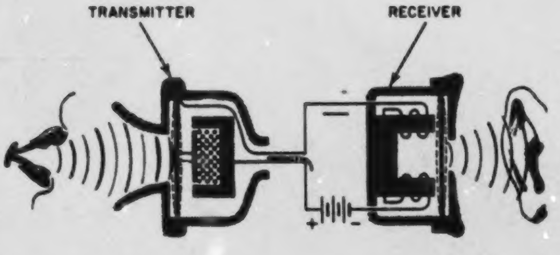
To get an idea of how the transmitter and receiver work, examine figure 12-2. Features of the transmitter are as follows:

1. It contains a chamber packed with small granules or grains of carbon.
2. The carbon granules are under pressure from a movable carbon disk at one end of the chamber.



73.170A

Figure 12-1.—Basic telephone circuit.



73.168A
Figure 12-2.—How transmitter and receiver work.

3. The movable carbon disk is itself directly attached to a flexible metallic diaphragm.

4. When the diaphragm vibrates forward, it pushes the carbon disk against the granules, thus subjecting them to pressure.

5. When the diaphragm vibrates backward, it releases the pressure on the granules.

Features of the receiver are as follows:

1. It contains a U-shaped permanent magnet.
2. It contains a flexible metallic diaphragm which is slightly attracted to the pole pieces of the permanent magnet.
3. It contains a pair of coils wound on the legs of the permanent magnet.

Now trace the electrical flow in figure 12-2. The electrons leave the negative terminal of the battery, travel through the coils of the magnet in the receiver, and then over to the transmitter. At the transmitter, the electrons pass down the metal diaphragm, into the carbon disk, through the carbon granules, and then back to the positive terminal of the battery.

You can see that, given a constant voltage, the amount of current which flows in the circuit will depend on the amount of resistance in the circuit. If the resistance is high, current will be low, and vice versa.

Now, the electrons meet resistance as they pass through the carbon granules. The amount of resistance offered by the granules depends on the pressure on the granules. If the pressure is high, resistance is low. If the pressure is low, resistance is high.

As you speak into the transmitter, you set up sound waves which strike the transmitter diaphragm. The diaphragm vibrates at the same rate as the sound waves. The carbon disk vibrates with the diaphragm, and thus alternately applies and releases pressure on the granules. This in turn varies the current to the coils of the receiver magnet. The varying current varies the strength of the magnet, and this varies the magnetic attraction on the receiver diaphragm. As the receiver diaphragm vibrates, it sets up air disturbances or sound waves which are identical with the ones which are sent into the transmitter.

This has been a very general explanation of how the telephone works. The following sections deal with advanced base telephone equipment in more detail.

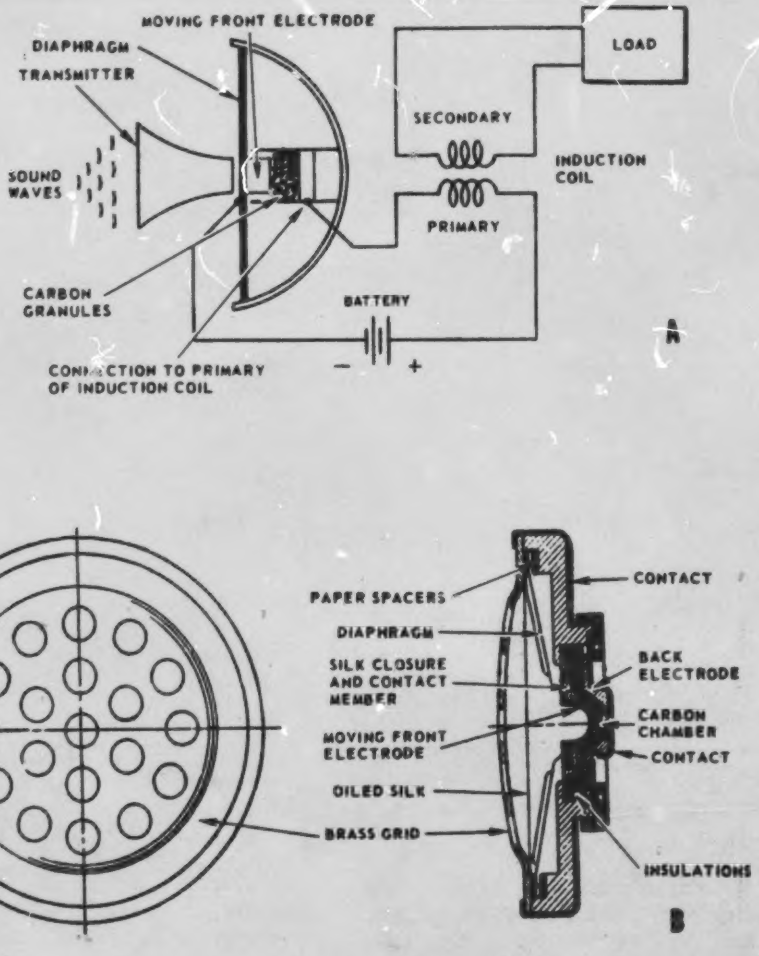
TRANSMITTER

The basic function of the transmitter and the way it performs that function were previously described. However, energy losses during transmission over the wires would naturally cause the useful energy at the receiver end to be less than that of the initial sound waves at the transmitter. Therefore, the circuit of the transmitter must be capable of amplifying the original energy of the sound waves in accordance with the line distance the energy must travel.

Various telephone subsets with carbon transmitters provide this necessary energy increase by the use of an induction coil, a device that functions like a transformer. The battery, the carbon, the diaphragm, and the induction coil compose the basic circuit, as illustrated in view A of figure 12-3. View B shows the construction of the carbon transmitter.

A bell-shaped chamber is packed with carbon granules, which have uniform contact with two gold-plated electrodes. The diaphragm is of flexible aluminum alloy, supported by paper spacers. The negative terminal of the battery connects with the diaphragm, which in turn rests against the chamber of carbon granules. The other side of the carbon chamber is connected with the primary of an induction coil. The return of the primary to the positive terminal of the battery completes the circuit. You can follow all of this in figure 12-3, view A.

Sound waves entering the diaphragm cause it to vibrate, and the moving front electrode exerts a varying pressure on the carbon. As the state of compression of the granules varies, the


MOVING FRONT ELECTRODE
DIAPHRAGM
TRANSMITTER
SOUND WAVES
CARBON GRANULES
CONNECTION TO PRIMARY OF INDUCTION COIL
LOAD
SECONDARY
INDUCTION COIL
PRIMARY
BATTERY
−
+
A
PAPER SPACERS
DIAPHRAGM
SILK CLOSURE AND CONTACT MEMBER
MOVING FRONT ELECTRODE
OILED SILK
BRASS GRID
CONTACT
BACK ELECTRODE
CARBON CHAMBER
CONTACT
INSULATIONS
B

73.167

Figure 12-3.—Carbon transmitter. (A) Circuit; (B) Construction.

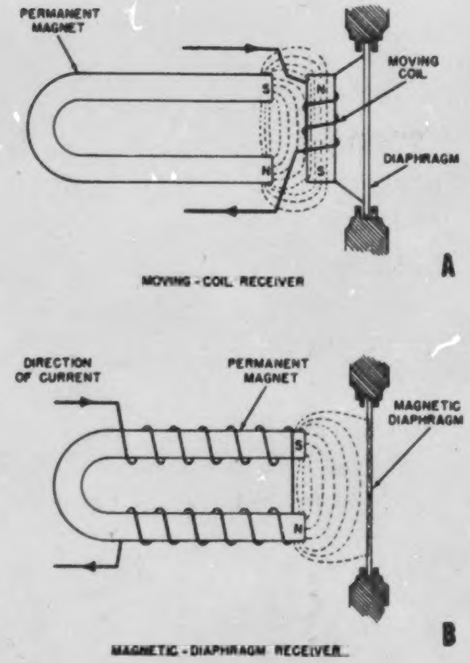
resistance also varies. As compression increases, resistance decreases, and the current in the circuit increases.

For example, if the battery has an emf (electromotive force) of 6 volts, and the carbon granules have a normal resistance of 300 ohms, the average value of current flow will be 20 milliamperes. When the diaphragm is made to vibrate (by speaking into it), the compression on the carbon granules may decrease resistance to 200 ohms, and current will consequently increase to 30 milliamperes.

On recently developed transmitters, sound waves intended to actuate the diaphragm should strike it at right angles, and from a very short distance. If the sound originates too far from the instrument, it will enter the transmitter from both the front and the back of the diaphragm, and thus will equalize pressure on the granules. The effect of these distant sounds, then, is practically zero. This type of transmitter has great value for military use, because it successfully cancels out background noises.

RECEIVER

Two common types of receiver, the moving-coil type and the magnetic-diaphragm type, are shown in figure 12-4. Both types are permanent-magnet devices, but the moving-coil type operates



73.168B
Figure 12-4.—Moving-coil and magnetic-diaphragm receivers.

on the same principle as a meter—that is, as the current in the moving coil varies, the magnetic field around the coil varies. As a result, the coil vibrates and causes the diaphragm to vibrate, which generates sounds of the same wave form and frequency as the current in the coil.

The magnetic-diaphragm type operates by variation of the strength of the magnetic field. Variations in amplitude and frequency of the magnetic field cause corresponding variations of motion in this diaphragm. This is the most common type used in telephone systems.

LOCAL BATTERY AND COMMON BATTERY CIRCUITRY

The electrical energy for a telephone circuit may come from a central source of power, or it may come from a local source, such as a dry cell, or a combination of dry cells.

When dry cells are used as the source of energy, the telephone installation is known as a local battery set. The cells provide the current for talking circuit, but signaling is usually produced by a small hand generator.

When a common or central source of power is used to provide energy, the system is called a common battery system. The source provides both signaling current (by means of a ringing machine attached to the power source) and current for the talking circuit.

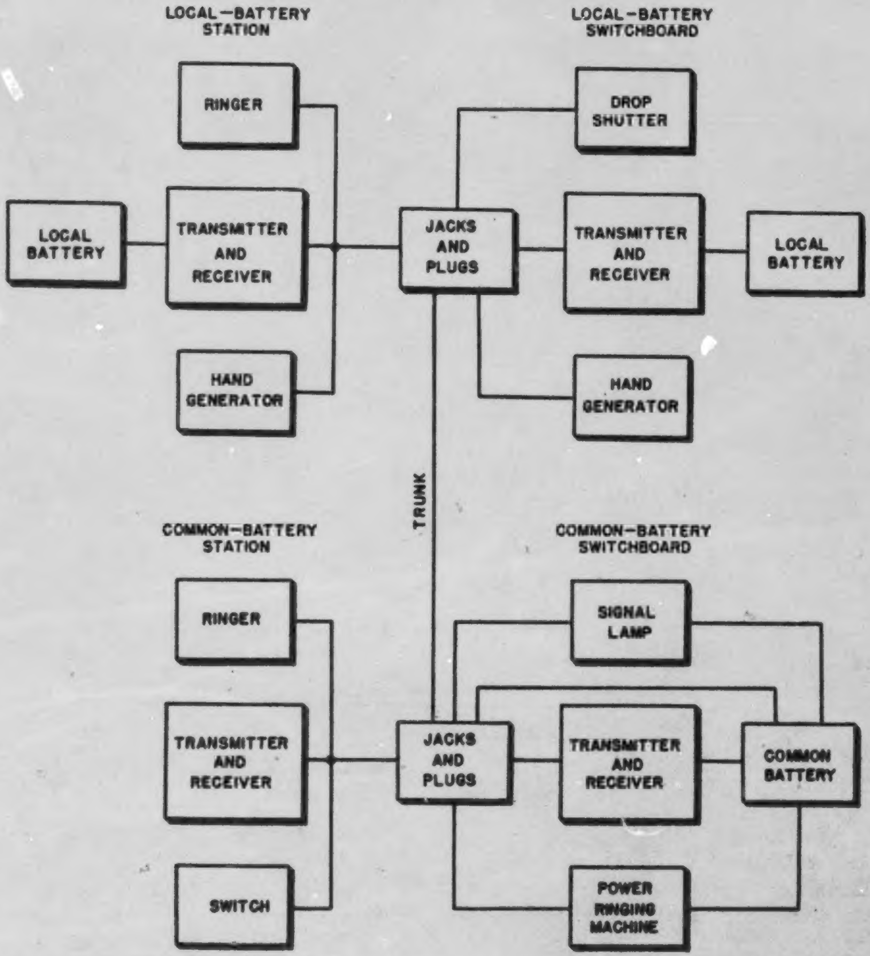
A manual installation at an advanced base may be the local battery type, the common battery system, or a combination of both. Where local battery sets are used, telephones may be connected directly, but connections are usually made through a switchboard.

Where a local battery system is established in the first days of occupation of an advanced base, it is possible to interconnect the switchboard of this emergency system with the switchboard of the common battery system, as soon as the latter has been established. A simple diagram for this type of interconnection is shown in figure 12-5.

The difference between a local battery and a common battery system is more than just the difference in power source. The location of the power source is also different. A local battery system has a battery (either one dry cell or several) at each telephone station. A common battery is centrally located, and serves all the stations of the system.

The common battery cannot serve all the stations unless the stations are in parallel with each other as far as direct current is concerned, and the battery is connected across the line instead of in series. The common battery, consequently, maintains a fairly constant voltage, and gives a more uniform signal than the local battery. This signal on the switchboard is automatic when the receiver is lifted; there is no necessity for the hand generator.

Advantages of the common battery system are that some of the equipment is simpler and cheaper, and inspection can be made at a single point to see if the cell or other power source is functioning. However, there is the disadvantage that the common battery system requires much better line construction than the


LOCAL—BATTERY STATION
RINGER
LOCAL BATTERY
TRANSMITTER AND RECEIVER
HAND GENERATOR
LOCAL-BATTERY SWITCHBOARD
DROP SHUTTER
JACKS AND PLUGS
TRANSMITTER AND RECEIVER
LOCAL BATTERY
HAND GENERATOR
TRUNK
COMMON—BATTERY STATION
RINGER
TRANSMITTER AND RECEIVER
SWITCH
COMMON—BATTERY SWITCHBOARD
SIGNAL LAMP
JACKS AND PLUGS
TRANSMITTER AND RECEIVER
COMMON BATTERY
POWER RINGING MACHINE

73.169

Figure 12-5.—Local battery system connected to common battery system.

local battery system needs. The switchboard equipment, too, must be more elaborate.

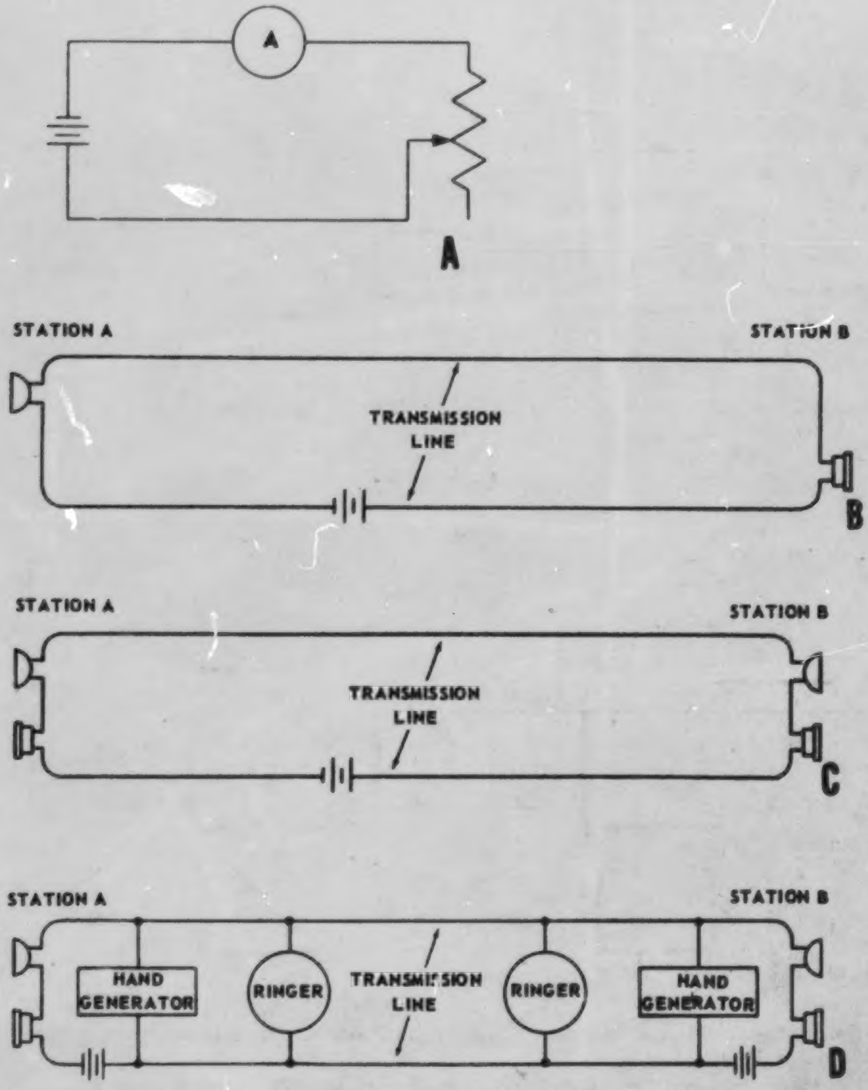
The hookup of the components of a simple telephone system are illustrated in the four drawings shown in figure 12-6. View A is a simple schematic diagram, showing the negative battery terminal connected to the ammeter, the ammeter to the resistor, and the circuit completed by connection from the resistor to the positive terminal of the battery.

View B shows the most elementary form of telephone circuit; a transmitter connected to a receiver. This would, of course, permit oneway conversation only.

View C shows a system which permits two-way conversation, but lacks a signaling device for alerting the receiving end to a call.

The circuit shown in view D, using dry cells alone, has a hand-generator-operated signaling device. However, line resistance, which increases with line length, would make this circuit practicable for short distances only.

What is lacking here is an induction coil—that is, a transformer device (primary coil and


A
A
STATION A
STATION B
TRANSMISSION LINE
B
STATION A
STATION B
TRANSMISSION LINE
C
STATION A
STATION B
HAND GENERATOR
RINGER
TRANSMISSION LINE
RINGER
HAND GENERATOR
D

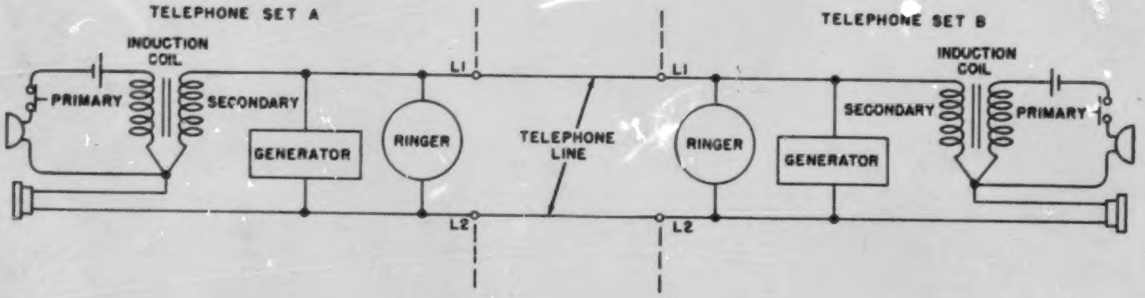
73.170

Figure 12-6.—Basic telephone circuits.

secondary coil) for stepping up the energy by magnetic induction. Putting a varying current in one coil induces an a-c voltage in the other, the value of the induced voltage depending on the ratio between the number of turns in the two coils and the rate at which the current changes.

Figure 12-7 shows induction coils in a circuit containing two local battery stations. Notice how, in each station, the primary coils are connected to the transmitter and to the battery. The secondary coil is connected to the receiver and to the line wires.

When you speak into the transmitter at set A, your voice causes a varying current to flow in the transmitter circuit. As this current passes through the primary coil, it produces an expanding



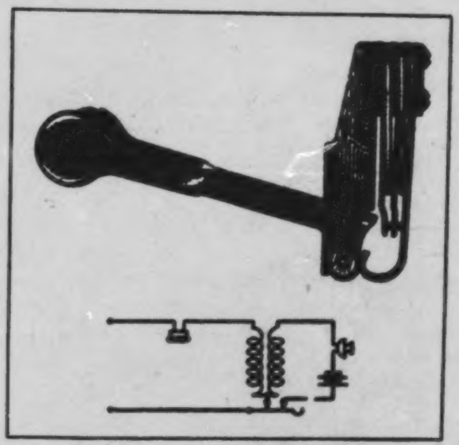
73.171

Figure 12-7.—Induction coils in circuit between local battery stations.

and contracting magnetic field. This field cuts the turns of the secondary coil, and induces a current in the secondary circuit. The receiver at set B reconverts this current to sound waves.

The secondary coil of the induction coil usually has more turns than the primary. Additional turns on the secondary coil give the same effect as a step-up transformer, and operate to cut down power losses.

Note that in the circuit illustrated in figure 12-7 there is a common connection between the primary and the secondary coils (a situation that does not exist in an ordinary transformer). This connection, however, does not affect the transformer action of the induction coils. It serves the practical purpose of reducing the necessary number of handset cord conductors. This common connection can also be used for such special circuits as the anti-sidetone circuit, which reduces the passage of voice currents from transmitter to receiver IN THE SAME SET.



73.172

Figure 12-8.—Hook switch.

HOOK SWITCH

In desk telephone subsets a hook switch (fig. 12-8) is used. The hook or cradle holds the receiver when the telephone is not in use. When the receiver is lifted, a hook spring forces two thin leaf springs together. Small buttons on the ends of the springs make the contact. The opposite ends of the springs are connected to the circuit, one spring being connected to the transmitter circuit, and the other to the incoming line. Thus both receiver and transmitter are put into action. Breaking the contact between the leaf springs (by putting the receiver back on the hook) also breaks the talking circuit.

MAGNETO GENERATOR

A small hand-operated generator is used in telephone circuits to provide signaling service. The generator is a magneto—because the magnetic field is provided by permanent magnets rather than by exciter coils. The generator is cranked by hand, and at a normal cranking speed it will develop an emf of from 80 to 90 volts, at frequencies of 16 to 20 hertz. Increasing the cranking speed will, of course, increase the generated voltage and the frequency.

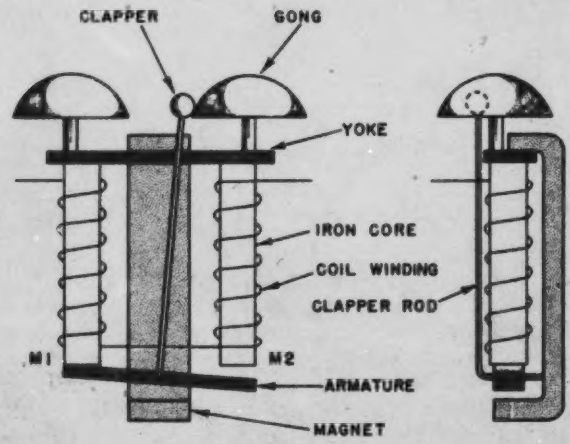
A spring switch actuated by the shaft of the crank handle provides a make-and-break contact, in that it connects the generator onto the line, and removes the bell from across the line.

A recently designed hand generator is provided with a dial, and you can either spin the dial or crank in the usual fashion. The crank is pivoted, and fits into a compartment on the dial face when not in use. The generator unit can be removed from the equipment and disassembled for servicing.

RINGER

The signaling device in a telephone set is usually a ringer—that is, an electric bell operating on low frequency (20 hertz) and powered by the hand generator. Figure 12-9 shows the operating principle of a ringer.

Two electromagnets, formed of coils wound on soft iron cores, are permanently joined at the upper ends by a yoke of soft iron. An armature is placed under the cores of the electromagnets, and pivoted at the center. A U-shaped magnet is secured at one end to the yoke that joins the electromagnets. The opposite end of the U is bent around the armature, but does not actually touch it. The armature carries a clapper rod which can vibrate between two gongs mounted above the yoke.



73.173
Figure 12-9.—Simplified diagram of a ringer.

When there is not current in the ringer, the magnetic lines of force are distributed evenly between the cores, and the armature is in balanced position. Alternating current through the ringer upsets this balance. By applying the left-hand rule for coils (explained in Basic Electricity) to M1 and M2 in figure 12-9, you observe that the magnetic polarity of M1 is opposite that of M2. The magnetic polarity of each will reverse every half-second, while the magnetic polarity of the permanent magnetic remains constant. Therefore, the lines of force of the permanent magnet are attracted to a different electromagnet every half-second. This causes the armature to vibrate rapidly between M1 and M2, which in turn causes the clapper to strike the gongs.

TELEPHONE SYSTEM DESIGN

An advanced base telephone system uses field wire on small installations and field cable for large installations.

Many of the problems which occur in relation to the installation and maintenance of military telephone systems are connected with increasing talking range, with the overloading of lines, and with interference which occurs when there is a transfer of electrical energy from one conductor to another. To understand these problems, you must have some knowledge of the principles of electrical theory as they apply to communications systems.

The electrical characteristics of communication transmission lines involve (1) power loss which increases with electrical length of line, and (2) distortion and interference caused by reaction of one line to a nearby line. These characteristics are complex and highly technical. Only the highlights can be discussed here.

ELECTRICAL LENGTH

The electrical length of a transmission line is not a linear dimension, but the relation between the length of the line (which is a linear dimension) and the wave length of the transmitted signal. It is this fact that makes electrical length an important factor in operating conditions.

A short line is one in which the length of the line is considerably less than the wave length of the transmitted signal. A long line is one in which the length of the line is equal to, or longer than, the wave length of the transmitted signal.

The wavelength is the ratio between the velocity of the electrical wave and the frequency of the signal. This may be expressed in the following formula.

$$\text{Wave length} = \frac{\text{Velocity}}{\text{Frequency}}$$

ATTENUATION

The general term for power losses along a transmission line or network is "attenuation." In an open-wire pair, attenuation depends on (1) the size, spacing, and material condition of the conductors, (2) the kind, number, and condition of the insulators, and (3) the frequency of the current. Under ordinary conditions there is less attenuation in an open-wire line than there is in cable or field wires.

LOADING

The talking range of a cable or field wire used for military communication is frequently increased by a procedure called loading. As applied to a transmission line, loading means increasing the series inductance of the line by adding external inductance. Lumped loading means the addition of loading coils with relatively high inductance at regular intervals along the line. This is the method most commonly used at advanced bases.

Continuous loading means wrapping the cable conductor with tape or wire made of magnetic material. This wrapping distributes the inductance continuously along the line and results in improved performance. Continuous loading is used on submarine cables, because lumped loading would subject them to excessive strain at the points where loading coils were inserted.

INTERFERENCE

Interference is a serious problem on telephone lines. It may result from lightning or other natural electrical disturbances in the atmosphere, or it may be caused by nearby power sources such as powerlines, railway facilities, or other communication circuits. When two or more telephone talking circuits operate in parallel with each other a transfer of electrical energy may cause crosstalk. When telephone lines run parallel to powerlines for a considerable distance, the transfer of electrical energy causes noises on the telephone lines. Battery chargers used to maintain storage batteries in a common battery system may cause a humming noise.

Interference may be kept to a minimum by maintenance of lines, transposing wires, balancing line capacitance, and using repeating coils, and noise filters. However, careful installation of lines and regular inspection of splices, joints, insulators, and other line equipment also helps to keep down noise. Methods and techniques for minimizing interference by proper installation were discussed in the chapter on the overhead distribution.

Capacitive coupling between adjacent telephone wires can also cause crosstalk. This effect can be reduced by transposing wires in the cable at points where one length of cable is spliced to an adjacent length of cable. Another method of reducing capacitive coupling is to connect the wires on one end of a short length of a twisted pair to the cable pair, leaving the wires on the other end of the short length unconnected.

In emergency installation, 1-wire ground-return telephone circuits may be used in conjunction with a 2-wire circuit. A 1-wire circuit is especially sensitive to inductive interference from adjacent circuits. Such interference can be greatly reduced by connecting the 1-line circuit to the 2-line circuit through a repeating coil.

Low-pass filters may be used to remove hum caused by battery chargers and similar equipment. These filters consist of a series of choke coils and shunt electrolytic condensers of rather large capacity. By filtering the output voltage, they remove the higher frequencies that lie in the voice frequency range.

TRANSMISSION SYSTEM PLANNING

Transmission lines used in military telephone installations may be field wires, open wires, or field cable.

Field wires consist of simple pairs of insulated wires twisted together. As a rule, you will use field wire chiefly for emergency and temporary installations. Transmission losses are so high that field wire lines must be confined to short lengths.

Open wires are parallel single bar conductors strung on pole crossarms.

A telephone cable consists of one or more pairs of wires, with each wire individually insulated. Field cable is available in 5-pair and 10-pair cable, color coded, rubber insulated, copper jacketed, and equipped with a connector on each end.

Begin planning by making a preliminary survey of the number of overhead and underground crossings the line must make, of the streams it must cross, of the general character of the terrain, and of any possible obstacles in the way of future maintenance work.

In routing, consider points where the lines might be damaged by construction operations, remembering that about everything at the base will be under construction at this time. When you have mapped the route along which the lines are to be laid, choose the wire or cable according to the type of line to be built.

FIELD WIRES

In laying field wire, select the shortest and the most effective route. At advanced bases, savings of time and of material can be very important factors. Surface line construction is the quickest type, but is vulnerable to weather conditions and mechanical damage. If the wires are surface-laid, they should be laid loosely, to minimize any damage from bombing.

Test the reels of wire for continuous circuit. Install test stations at exposed points on the wire line—for example, where circuits diverge (or may diverge with future expansion of the system), and at the end of a line that does not terminate in a switchboard. In the actual laying of a line, you will find additional points at which it will be desirable to set up test stations.

Use overhead lines near headquarters and camp areas, and at road points where it is likely that traffic will be diverted from the road.

Trees can be used as supports for overhead wires, but they may sway during high winds. To offset this, a slightly more-than-normal sag should be provided. In some cases you may have to use slings to give intermediate support.

If field wire is placed on poles carrying bare conductors, it must be strung below the lowest bare conductor. Precautions must be taken to ensure that, in swinging or otherwise, telephone wire will not contact the bare conductor.

At junctions between overhead and surface lines, tie the wires securely to the bottom of the support and tag them. Where there are long stretches of overhead lines, install test stations at junctions with other types of construction.

OPEN WIRES

For open wire installations, you will use steel wire, hard-drawn copper wire, or copper-clad steel wire, diameter from 80 to 165 mils. Two wires constitute a line.

The conductors are strung on electrical insulators mounted on the crossarms of telephone poles. As each basic telephone circuit requires two wires, you will have to mount quite a number of bare conductors on the crossarms. Keep each conductor in place by tying it to an insulator. Standard spacing distances are 8 in. for a single pair of wires, 10 to 12 in. when more than one pair are strung.

The procedure for stringing telephone wire is similar to that for stringing powerline wire. You should know the main operations (reeling out the wires, raising wires to crossarms, tensioning, and tying in) by now.

TELEPHONE CABLE

Because of the numerous wires that are carried in a cable of nominal cross section (as, for example, 1 1/2 in. in diameter), there are certain disadvantages in using cable. The voltages carried are low, which means that a single wrap of dry paper is insulation enough for each wire. However, this insulation is so thin, and the wires are so tightly packed, that a very small amount of moisture can produce a short.

TYPES OF TELEPHONE CABLE

The following are commonly used types of telephone cable:

1. Exchange cable is the outside cable of a central office that furnishes the facilities for sending out and receiving calls through local switchboards.
2. Toll cable is a quadded or nonquadded conductor (the term "quadded" means that all

or some of the conductors are arranged in quads, or groups of two pairs) used for communication between widely separated local exchanges.

3. Trunk or tie cable is used primarily for connecting exchanges which are fairly close together.

Post or administrative cable forms part of a fire control communications system. Target range cable is used exclusively on a target range, and is not connected to any other system. Fire alarm cable is used exclusively in a fire alarm system.

OVERHEAD CABLE LINE

Open wire needs no intermediate support between poles. Telephone cable, however, must be supported between poles by a series of metal rings which are suspended from a galvanized steel wire called a suspension strand or messenger, or the cable is held to the messenger by a process known as spinning or spun cable. A small wire (or wires) is spun around both the cable and the messenger by a machine called a cable lashing machine.

Suspension Clamps

The first step in stringing the messenger is to provide support at each pole by installing a suspension clamp. One of these clamps consists of two metal bars which can be clamped together by tightening a nut and bolt assembly. An overhanging lip on one of the bars forms a groove that holds the suspension strand.

Stringing Suspension Strand

When suspension clamps have been mounted on all the necessary poles, you can string the suspension strand. As the strand is unreeled, it is carried up each pole, and placed in the suspension-clamp groove. The clamp nuts should be tightened only enough to keep the strand from falling out.

The next step is to pull the suspension strand to the proper tension or sag. Leading the pulling line through a snatch block (block on which the side strap can be opened for inserting a line or wire when the end is not available) set at the top of the pole will prevent the suspension strand from being pulled out of the grooves on the clamp.

After the suspension strand has been pulled to the specified sag, it must be dead ended. You can terminate the strand at the eyebolt used for the guy wire. Thread the free end of the strand through a thimble in the eyebolt, then double it back and clamp it to the main part of the strand, or use a preformed dead end grip.

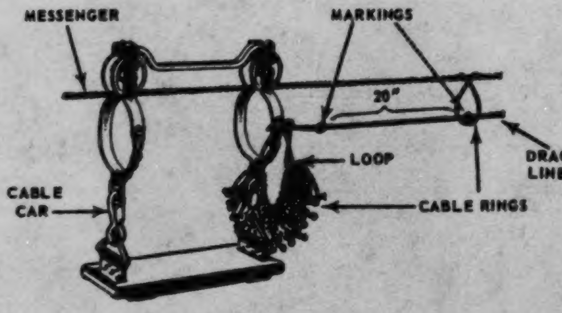
The last step in the installation of suspension strand is the tightening of the suspension clamps. At first you tightened them just enough to hold the strand in the groove. Now they must be fully tightened. It is best to start at the middle pole and work toward each end in turn.

Cable Rings

One method of fastening the cable to the supporting suspension strand is to use cable rings. To string these rings on the suspension strand you will probably use a cable car like the one shown in figure 12-10. A loop of wire attached to the car holds the rings. A drag line, marked with the ring spacing as shown, is left threaded through each ring as the car passes along. The drag line then serves as a pulling-in line when you are ready to pull the cable through the rings. If you line the reel up carefully with the suspension clamp, the cable should pull smoothly through the rings.

Lashings

Instead of being suspended on rings, the cable may be lashed to the suspension strand. First the cable is brought up to the strand. Then the two



73.175
Figure 12-10.—Cable car for placing rings.

are lashed tightly together with a spirally wound wire using a cable lashing machine (fig. 12-11).

To bring the cable up to the strand, you can use temporary cable rings, which can be removed as soon as the lashing is applied. An alternate method is to mount the cable reel on a truck, and pay the cable up to the suspension strand through a cable guide (shoe) to which the lashing machine is attached.

UNDERGROUND TELEPHONE LINE

The advantage of direct burial of telephone cable, a method frequently used in laying field cable, lies in the fact that an underground system is usually much easier to construct than an overhead system.

Protection against corrosion and damage is provided by placing the cable in ducts, a method which also facilitates pulling in and replacing cable when necessary. Manholes and splicing chambers constructed at intervals along the line serve as convenient points for inserting cable in ducts.

Make the trench no wider than necessary, but deep enough to allow 18 inches of earth cover over the cable. Remove any rocks that might damage the cable. Where a reel runs out, bring the end of the wire into a splicing chamber, or up to the ground surface, to splice it. Backfill excavated earth with a grader or bulldozer.

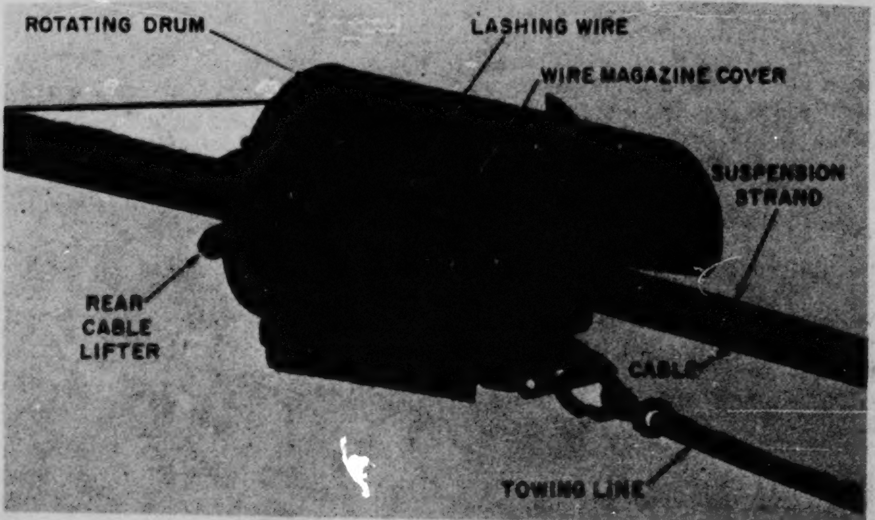
Again as with underground powerline ducts, have the trenches slope toward the manholes for drainage. Make sure that ducts have been cleaned of dirt or concrete before pulling cable through. Push a rodding tool through from one manhole to the next. Attach a threading wire to the last section of rod in the rodding tool, and a rope to the threading wire. When the rope appears in the manhole, fasten the end to the pulling source of power. Fasten the other end to a cable grip on the cable to be pulled through.

OUTSIDE TERMINALS

In carrying telephone wires from switchboard to subsets, there will be numerous places where the cable will have to be spliced. Methods of splicing telephone cable are described in chapter 13.

Terminal boxes are mounted at convenient points along the pole lines—two or more boxes must be used, if the number of telephones to be installed exceeds the number of terminals in a single box.

The appropriate wires are brought out from the cable and connected into these boxes.



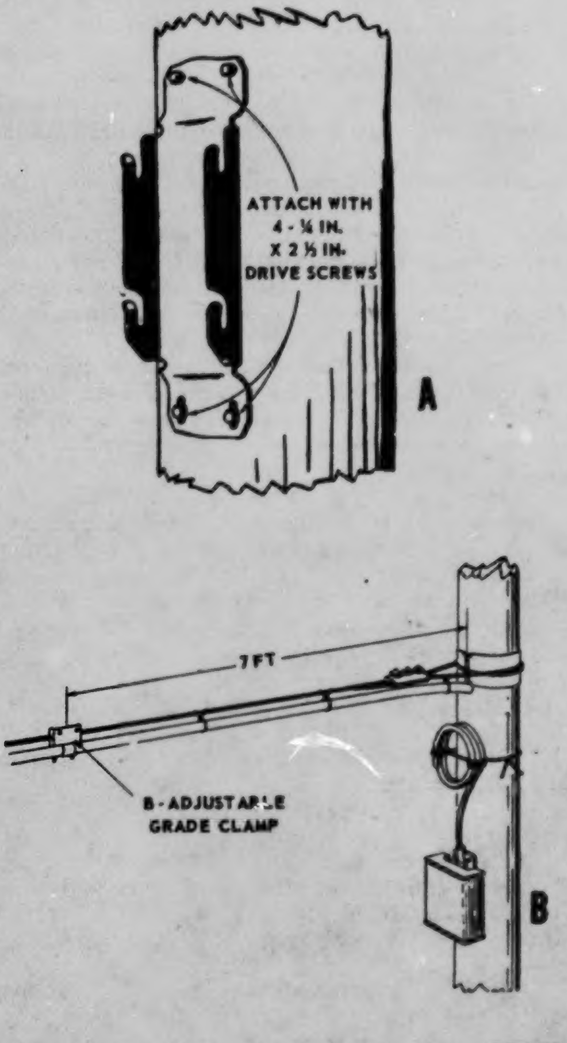
73.337

Figure 12-11.—Cable lashing machine.

Outside drop wires are then installed to lead from the terminal boxes to the substations.

Mounting Terminal Boxes

Mounting terminal boxes on poles is a job commonly given to the CECN. A can bracket is first attached to the pole, about 24 in. below the main cable, by four screws. The terminal box is then placed in supporting notches in the bracket, (See fig. 12-12.)


ATTACH WITH
4 - ¼ IN.
X 2 ½ IN.
DRIVE SCREWS
A
7 FT
B - ADJUSTABLE
GRADE CLAMP
B

73.177
Figure 12-12.—(A) Can bracket for pole-mounted box; (B) Box installed in bracket.

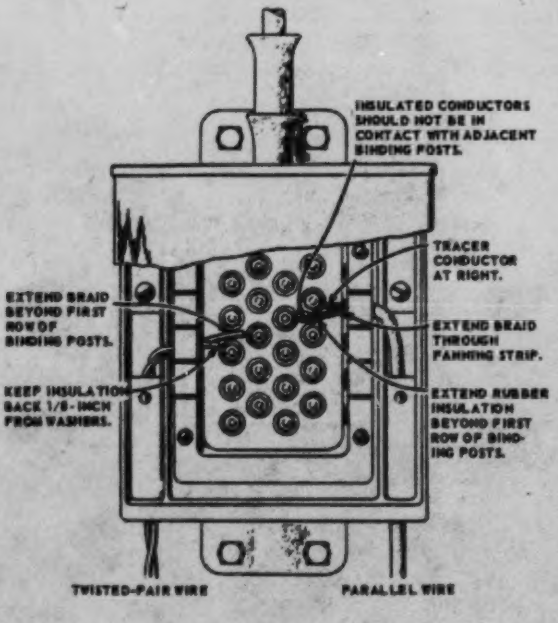
Terminal Box Panel

Inside a terminal box there is a panel fitted with binding posts, nuts, and washers. A short length of lead-sheathed cable is attached at the back of the box. Drop wires from the individual subsets are attached to the binding posts.

Figure 12-13 shows how connections are made at the panel of a terminal box. As soon as the wires in the cable stub are spliced to the wires in the main run of cable, you will have a completed circuit from main line to subset. In figure 12-12 you can see the cable stub coiled and ready for splicing to the main line. Tapping the main line, and calling the wire chief or switchboard operator to assure proper line number and subset operation, is usually the last step in telephone installation.

TELEPHONE SWITCHBOARDS

Connecting a large number of telephone stations directly to each other would require an enormous maze of wires. To reduce the amount of wiring and to simplify the wiring arrangement, a switchboard is installed in the system


INSULATED CONDUCTORS SHOULD NOT BE IN CONTACT WITH ADJACENT BINDING POSTS.
TRACER CONDUCTOR AT RIGHT.
EXTEND BRAID BEYOND FIRST ROW OF BINDING POSTS.
EXTEND BRAID THROUGH FANNING STRIP.
KEEP INSULATION BACK 1/8-INCH FROM WASHERS.
EXTEND RUBBER INSULATION BEYOND FIRST ROW OF BINDING POSTS.
TWISTED-PAIR WIRE
PARALLEL WIRE

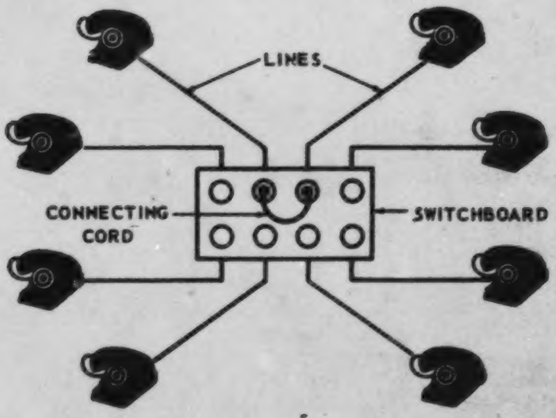
73.176
Figure 12-13.—Connections at terminal box.

Figure 12-14 shows how a switchboard simplifies connection between eight telephone stations. Each station is connected directly to the board. Connection between any pair of stations can be made at the board by means of a plug-fitted cord. Particular types of switchboard are discussed later in this chapter.

DISTRIBUTION FRAMES

When a large number of lines come into a switchboard, there must be some arrangement for rapidly connecting them to the proper jacks on the board. This is accomplished by the use of distribution frames. These frames not only provide for an orderly arrangement of incoming lines, but also serve as an effective means for identifying outside lines where they enter the central office. Main distribution frames (MDF), either in manual or in dial systems, serve these two purposes. They connect the inside equipment with outside lines, and they interconnect the various units of inside equipment. Figure 12-15, view A shows the vertical side of a combined distributing frame. Figure 12-15, view B shows the horizontal side.

Each outside line is connected to a PAIR of terminals on one side of the frame, as shown in figure 12-16. Notice how the corresponding terminals on the opposite side of the frame are connected to lines to the switchboard. For each line in use (that is, connected up in this fashion), jumpers or cross-connecting wires make a connection between terminals.



73.178
Figure 12-14.—How eight telephones can be connected by switchboard.

The side of the frame carrying the terminals to which outside wires are connected is usually known as the vertical side of the MDF. Cables or lines from the inside equipment terminate on what is usually called the horizontal side (in some installations, however, both sides are vertical). Cross connections between vertical and horizontal sides are made by jumpers.

The use of distribution frames permits rapid switching of the switchboard load. It also makes outside wires accessible without any disturbance of the switchboard wiring, and provides a convenient place from which to test for line faults.

Distribution frames may be either the wall frame or the floor frame type. Wall frames are used in small central offices, and consist of units capable of accommodating 20 pairs, or lines. Screw type terminals are frequently used, because they allow for easy disconnections. Jumpers are flexible and can be made fast to any set of terminals. Standard floor frames, also used at military installations, differ from wall frames in that they have one side vertical and one horizontal, while a wall frame has two vertical sides.

Besides being distinguished as wall or floor frames, distribution frames may be distinguished as type A or type B. The type A frame has the vertical side of the frame connected to the switchboard. The type B frame has the vertical side connected to outside lines.

SWITCHBOARD PROTECTIVE DEVICES

Because the distribution frame is the dividing point between the outside plant and the inside plant, it becomes the logical location for central office protective devices.

The switchboard must be protected against excessive voltage, including that caused by lightning; and against excessive current, including current surges through unexpected channels. The protective devices must operate before

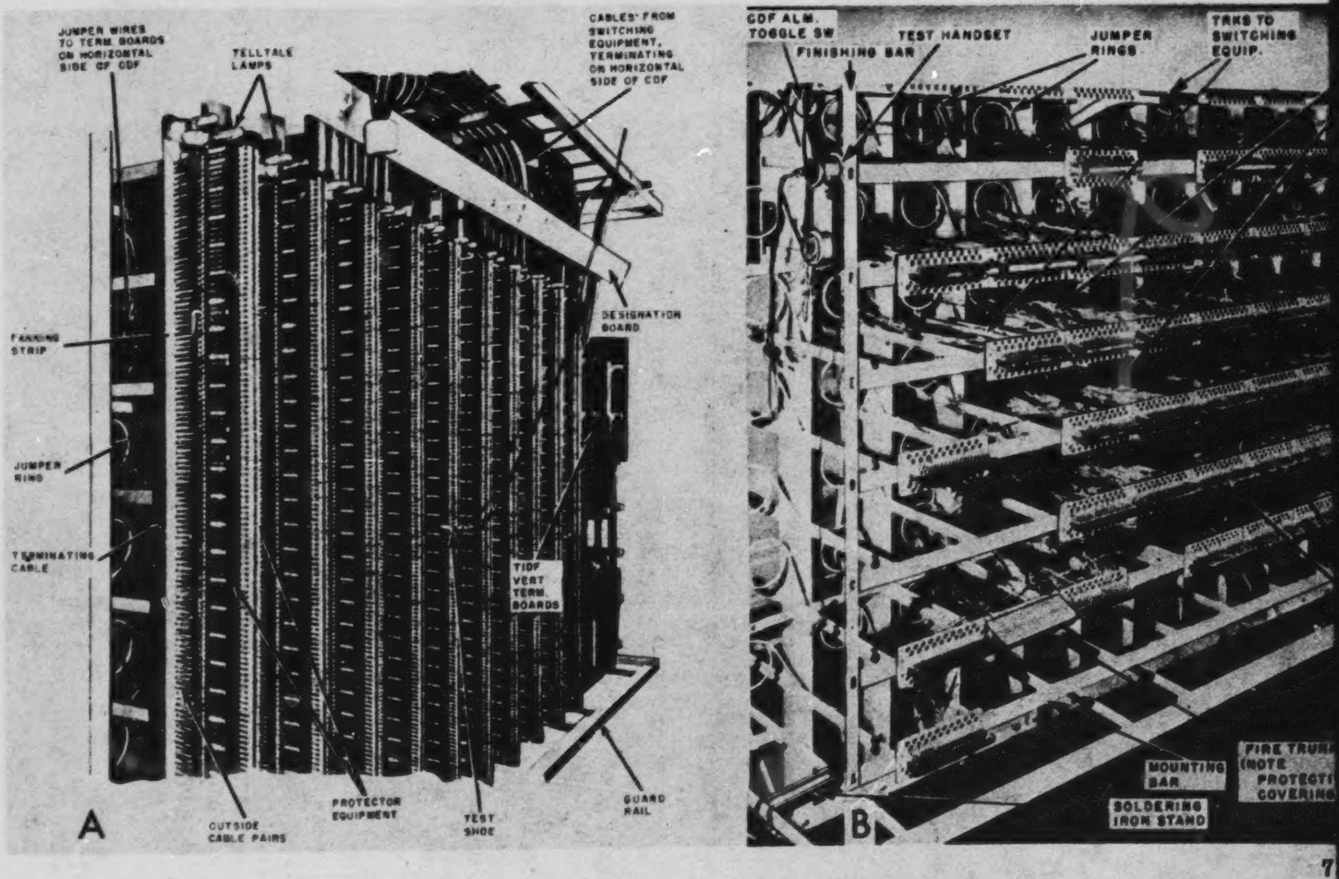
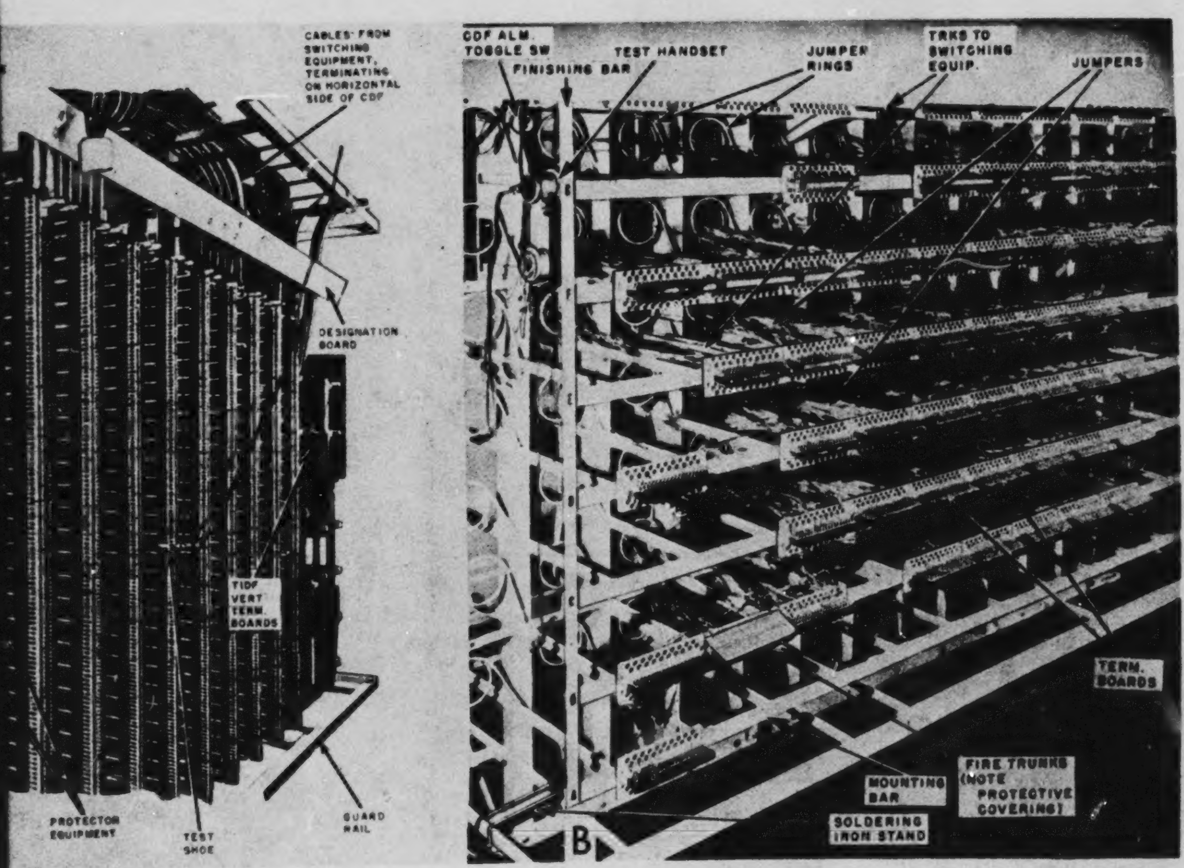
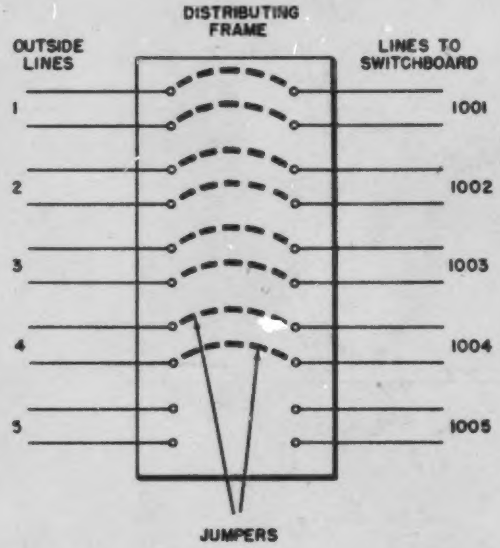

JUMPER WIRES TO TERM. BOARDS ON HORIZONTAL SIDE OF CDF
TELLTALE LAMPS
CABLES FROM SWITCHING EQUIPMENT, TERMINATING ON HORIZONTAL SIDE OF CDF
DESIGNATION BOARD
FANNING STRIP
JUMPER RING
TERMINATING CABLE
TIDF VERT TERM. BOARDS
GUARD RAIL
TEST SHOE
PROTECTOR EQUIPMENT
OUTSIDE CABLE PAIRS
A
CDF ALM. TOGGLE SW
TEST HANDSET
FINISHING BAR
JUMPER RINGS
TRKS TO SWITCHING EQUIP.
MOUNTING BAR
FIRE TRUN (NOTE PROTECTI COVERING
SOLDERING IRON STAND
B
7

Figure 12-15.—(A) Combined distributing frame, vertical side (B) Distributing frame, horizontal side.


CABLES FROM SWITCHING EQUIPMENT, TERMINATING ON HORIZONTAL SIDE OF CDF
DESIGNATION BOARD
TIDF VERT TERM. BOARDS
PROTECTOR EQUIPMENT
TEST SHOE
GUARD RAIL
CDF ALM. TOGGLE SW
FINISHING BAR
TEST HANDSET
JUMPER RINGS
TRKS TO SWITCHING EQUIP.
JUMPERS
TERM. BOARDS
MOUNTING BAR
FIRE TRUNKS (NOTE PROTECTIVE COVERING)
SOLDERING IRON STAND
B

73.179(73B)

—(A) Combined distributing frame, vertical side (B) Distributing frame, horizontal side.



73.179(73G)
Figure 12-16.—Connections made through distribution frame.

damage occurs, but they must not be sensitive enough to interrupt service by functioning as a result of lesser types of artificial or natural disturbance.

Air gap arresters provide protection against excessive voltage. Protection against accidental current surges is required only if the excess flows for an appreciable interval; a heat coil is the best protective device here.

Fuses protect against excessive current other than instantaneous surges. In a large central office there may be hundreds of switchboard fuses, to protect the switchboard from its own battery current if the current flow is too high.

CIRCUITS

On a common battery switchboard there will be a telephone relay circuit, a common battery line circuit, common battery cord circuits, and the "operator's telephone circuit." These are described in the following paragraphs.

Relay Circuits

The relay is a control device which provides for automatic signaling on the common battery system. A relay is, in effect, an electrically operated switch which makes it possible to control (by means of one switchboard circuit) the operation of one or several circuits on other switchboards. There are many different types of relays, as far as construction goes, but the principle of operation is the same for all.

Essential parts of a relay are: armature, windings, core, and springs. It is the motion of the armature that opens or closes the controlled circuit. Windings provide the path for current flow. The number and types of winding depend upon the particular function of the relay. The core is the magnetic material. The contact springs are of silver or silver alloy, and operate either normally open or closed. The number and arrangement of contact springs depend on the strength of the magnetic field, which in turn depends upon the number of turns and the value of current in the windings.

Relays are provided with covers, to keep out dirt and to protect against mechanical injury. Some have a small setscrew, called a residual screw, which can be adjusted to overcome residual magnetism in the armature.

Common Battery Line Circuits

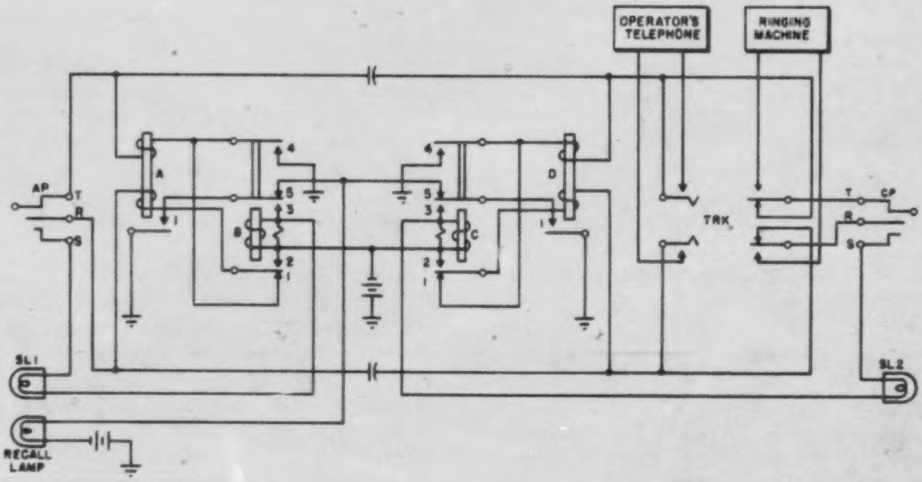
Common battery line circuits are of three types, as follows:

1. Series lamp line circuit, with a lamp connected through the auxiliary contacts of a cutoff jack.
2. Series relay line circuit, in which a relay is included, in addition to a lamp and cutoff jacks.
3. Cutoff relay line circuit, in which a cutoff relay is substituted for the auxiliary contacts of a cutoff jack.

Cord Circuits

Cord circuits prevent the branch containing the common battery from shorting out the receiver of the listening station. A retardation-coil cord circuit uses a relay to provide automatic supervisory signals. A repeating-coil cord circuit uses separate relays (supervisory relays) for this purpose.

A third type of cord circuit, called a universal cord circuit, is often used on military switchboards that serve both common battery and local battery stations. Such a circuit is shown in figure 12-17. It supplies battery voltage to the common battery lines, but not to the local battery lines.



73.180

Figure 12-17.—Universal cord circuit.

This circuit is called universal because it provides a talking circuit in either direction between two common battery lines, or between two local battery lines, or between one common battery line and one local battery line.

The various cord circuits provide for ELECTRICAL paths between selected stations, but they are not sufficient of themselves to enable the user of a calling telephone to tell the switchboard operator what station he wishes to call. For this, it is necessary that the operator be able to listen to or talk into each telephone. This need is met by installing an operator's telephone circuit for the entire switchboard.

Operator's Telephone Circuit

The function of this circuit is to connect the operator's telephone set across the line from any calling station, either before or after the called station is connected. The operator's telephone circuit, therefore, provides an additional voice frequency path which is in parallel with the cord circuit.

Generally, the operator's set is connected to the switchboard by means of a plug and jack. A lever switch allows the operator to cut his telephone into or out of any cord circuit. It differs from user's set in having no ringer and no hook switch contacts. Switchboards signal drops or lamps perform the function of the ringer. Operator's jack, plug, and lever switch substitute for the hook switch.

RINGING MACHINES

A ringing machine is a device that operates from a standard power source to provide ringing current for the switchboard and connectors. A variety of devices are available to meet different requirements. In any case they convert the a-c or d-c voltage of the power source to the required frequency (usually 20 hertz) of the ringing current.

If the power input is from a battery, a d-c vibrating reed CONVERTER changes the d-c to 20 hertz.

An a-c vibrating reed INTERRUPTER produces 20-hertz ringing current output from a 110-volt 60-hertz input. This is accomplished by alternately opening and closing the output circuit at regular intervals. The interruption of the output circuit results in an output voltage consisting of alternate positive and negative half-cycles which, over a 1-second period, are the equivalent of a 20-hertz frequency variation.

The machines described above have moving parts which need frequent adjustment and are difficult to maintain. Subcycle static frequency converters have been designed to minimize maintenance and replacement of parts. This device is essentially a series L-C circuit designed to resonate at 20 hertz. A switching action, accomplished electrically by a saturable reactor, allows the 60-hertz current to turn off and on at the proper times to develop the 20-hertz current.

SWITCH KEY

The switch key on the switchboard is simply a make-and-break spring switch. When you move the key handle, it causes a cam to press against the spring of the switch, and to open or close the contacts in the cord circuit.

When the switchboard operator receives an incoming call, he pushes the key forward into the talking position. When he has made the connection with the circuit on which the call is to be placed, he pulls the key back into ringing position. When the calling party has a connection with the called party, the operator lets the key return to neutral position. There is now a closed circuit from calling to answering plug. This circuit is broken when one of the telephones is returned to its cradle.

INSTALLING A TELEPHONE

After you have strung the outside lines, installed the switchboard, and provided for the necessary connections between main lines and subsets, then a telephone can be installed. The steps for installing a telephone will be briefly outlined here, then explained at more length in subsequent section.

Span the drop wire from the pole to the building, and train it along the building to the entrance hole. Bring it through the hole, and connect it to the INPUT side of the fuse, lightning arrester, or other protective device.

Connect the inside wiring to the OUTPUT side of the protector; run the inside wiring to the subset location; and terminate the inside wiring at the connecting block.

Attach the subset wires to the connecting block; secure the drop wire to the pole; tap it to the designated pair of wires in the main run (through the terminal box if cable is used; directly to a pair of open wires if the main run consists of open wires strung on crossarms); and finally check the installation.

WIRING

The drop wire is exposed to the weather, and both wind and rain can do damage unless the wire has been given proper protection. Both conductors should be insulated with a rubber compound, and the wire should then be further protected with a covering of weatherproof cotton braid. The wire used inside a building is rubber insulated, but protective braid covering is not necessary, except in very damp locations.

Drop wire may be either the twisted-pair type or the parallel-drop type. The twisted pair consists of two conductors separately covered but spiraled together. In a parallel-drop wire there are two separately insulated wires that run parallel to each other and are under a single braid covering.

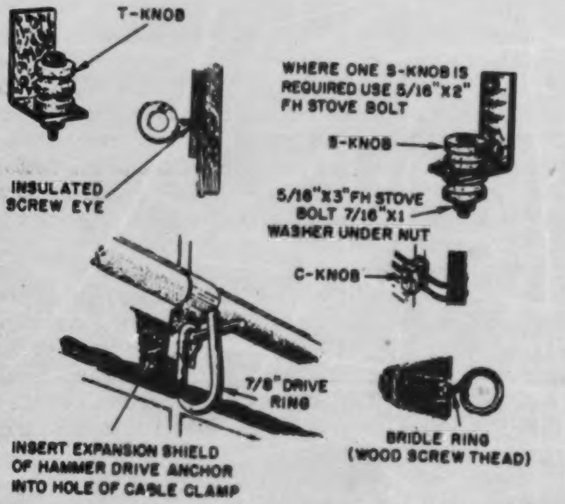
The drop wire must have a definite sag between pole and building, but the weight of the wire should not be allowed to exert a strain on the remainder of the run. Clamping the drop wire prevents this.

The clamp installation consists of a wedge secured to a copper wire loop, and a tapering sleeve. The copper wire loop is attached to the support point on the pole. Then the sleeve is placed over the drop wire, with the tapered end toward the support point, and pushed firmly up on the wedge. When the free end of the drop wire is attached to the building, the weight of the span induces a tight fit at the wedge.

The type of support you use to train the drop wire along the building depends on the material of the building wall. On wood or other combustible material, supports must be insulated. Anchor bolts are used on concrete and masonry walls. Toggle bolts are used on clay tile walls. Some commonly used types of supports on various kinds of walls are shown in figure 12-18.

Wire can be run on a sheet-metal wall (such as the wall of a quonset hut) without the necessity for drilling into the metal. Nail knobs (similar to the T-knob shown in fig. 12-18, but with a nail instead of a bolt) can be driven into points where the sheet metal is secured to the rib-frames. On a metal base the knobs must, of course, be insulated.

On a frame building you can attach the drop wire with an S-knob (fig. 12-18) and a drop wire


T-KNOB
WHERE ONE S-KNOB IS REQUIRED USE 5/16"X2" FH STOVE BOLT
S-KNOB
INSULATED SCREW EYE
5/16"X3"FH STOVE BOLT 7/16"X1 WASHER UNDER NUT
C-KNOB
7/8" DRIVE RING
BRIDLE RING (WOOD SCREW THEAD)
INSERT EXPANSION SHIELD OF HAMMER DRIVE ANCHOR INTO HOLE OF CABLE CLAMP

73.181

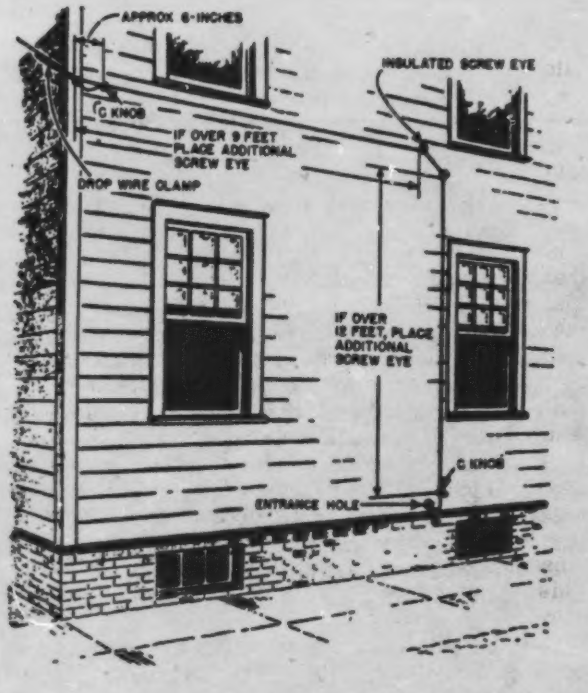
Figure 12-18.—Supports for telephone wires.

clamp. In a line with the S-knob, and about 6 in. away, screw in a C-knob (fig. 12-18). Still following a horizontal line, attach an insulated screw eye (fig. 12-18) a few feet further along. The horizontal distance will depend on the location of the entrance hole, because you want the wire to drop from a point vertically above the hole. Screw in another insulated screw eye and another C-knob as shown in figure 12-19, if the indicated distances exist.

Figure 12-19 will aid you in installing a drop wire. You attach the drop wire clamp to the drop wire and attach the clamp to the S knob. Allow a slack loop of about 12 inches (6 inches for slack and 6 inches to the first C knob). Place the drop wire in the C knob. Tighten it down and run it through the necessary insulated screw eyes to the last C knob. Allow a 4- to 6-inch drip loop between the last C knob and the entrance hole. A plastic or porcelain tube is usually inserted in the hole to protect the entering wire. Where a protector is used, the DROP LOOP ends in the protector, and the inside wiring goes through the tube.

CONNECTIONS TO PROTECTORS

The wire from pole to building usually crosses light and powerlines, and is always exposed to the possibility of being struck by lightning. It therefore requires some protective device, such as a fuse or lightning arrester. This protector may be enclosed in a weather-proof metal can outside, or it may be an inside unit mounted on a porcelain block.


APPROX 6-INCHES
INSULATED SCREW EYE
C KNOB
IF OVER 9 FEET PLACE ADDITIONAL SCREW EYE
DROP WIRE CLAMP
IF OVER 12 FEET, PLACE ADDITIONAL SCREW EYE
C KNOB
ENTRANCE HOLE

73.182

Figure 12-19.—Drop wire installation on wood frame building.

Fuses are inserted in series with the line, but an arrester is placed between line and ground. With a fuse, current must pass through the fuse before it can reach the output terminals to which the subsets are connected. An arrester ensures that excessively high potential is bypassed to ground before it can reach the output terminals.

When you bring in the drop wire, remove the insulation for about 3/8 in. from the end, and then bring the bare ends of the conductors around the input terminal posts on the protector. Give each wire a 3/4 clockwise turn around its post, and then tighten the terminal nuts.

Connect the inside wiring to the output terminals—that is, to the outside binding posts on the bottom of the protector.

The center terminal is the ground terminal for the arrester. Connect it, by a single insulated conductor, to a cold water pipe, if possible. If there is no available metallic object in close contact with the ground, drive a ground rod. NEVER ground to gas pipe systems or to lightning rods. Hot water, steam, or sprinkler pipes provide poor grounding, and electric railways should never be used to ground any equipment other than that supplied by the railway's own circuit.

CONNECTIONS TO SUBSETS

In routing the inside wiring from protectors to subset locations, keep the run parallel with or at right angles to the building walls. Wherever wires must pass around sharp corners or over metal objects, use friction tape to protect them from mechanical injury. If you must run wiring along a floor or ceiling, place it in a metal raceway for protection. You can secure inside wiring to walls and ceilings with insulated staples, because inside wiring carries a protected low voltage.

At the telephone location, run the inside wire to the connecting block. One of these blocks usually consists of four terminal posts mounted on a composition base and provided with a removable cover.

Bring the inside wire to the back of the connecting block, wind it around the projecting lugs, and connect it to the terminal posts on the face of the block. There will be less strain on the wire than if the connection were made directly, and there will also be enough wire so that it can be reconnected if a bare end breaks off.

These connecting blocks provide not only a point at which to connect inside wire and telephone cord, but also a convenient test point.

CONNECTIONS TO THE MAIN RUN

Before you can make final connections with the main run, there is the matter of training the drop wire back to the connecting point in the run. The method to follow in doing this will depend upon whether the drop wire is to be connected to open wires or to a terminal box.

If the drop wire is to be connected to open wires, train it under the crossarm to the point of connection. Use bridle rings to support the drop wire along the crossarm. The type of bridle ring you will use has an open spiral eye through which you can slip the wire after the ring has been screwed into the crossarm.

Each conductor of the drop wire should be separate, as if for splicing. You can then wrap each of the two conductors around the main run wires, for about three turns, before extending the conductors to the point of connection. The crew chief will tell you which pair of wires to use in the main run.

The joint at the connection is solderless. The connector will probably have a slotted bolt, nut, and washer assembly. Place the main wire in the slot, and wind the bared conductor of the drop wire around the bolt, between two washers. Be sure to wind in the same direction in which the nut tightens. Turning down the nut will ensure a firm joint.

Terminal boxes were previously described. The method of connecting a drop wire to a terminal box is illustrated in figure 12-20. Important matters to bear in mind are: connect the pairs of binding posts to the proper wires in the main cable; remove only a small amount of

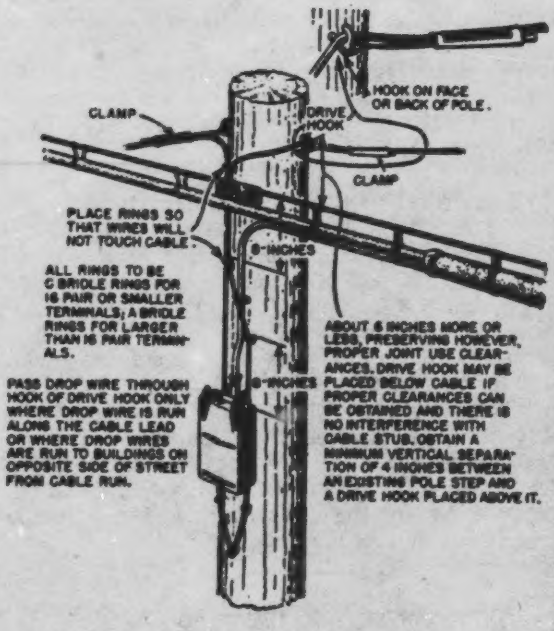

CLAMP
DRIVE HOOK
HOOK ON FACE OR BACK OF POLE.
CLAMP
PLACE RINGS SO THAT WIRES WILL NOT TOUCH CABLE.
8-INCHES
ALL RINGS TO BE C BRIDLE RINGS FOR 16 PAIR OR SMALLER TERMINALS; A BRIDLE RINGS FOR LARGER THAN 16 PAIR TERMINALS.
ABOUT 6 INCHES MORE OR LESS, PRESERVING HOWEVER, PROPER JOINT USE CLEARANCES. DRIVE HOOK MAY BE PLACED BELOW CABLE IF PROPER CLEARANCES CAN BE OBTAINED AND THERE IS NO INTERFERENCE WITH CABLE STUB. OBTAIN A MINIMUM VERTICAL SEPARATION OF 4 INCHES BETWEEN AN EXISTING POLE STEP AND A DRIVE HOOK PLACED ABOVE IT.
PASS DROP WIRE THROUGH HOOK OF DRIVE HOOK ONLY WHERE DROP WIRE IS RUN ALONG THE CABLE LEAD OR WHERE DROP WIRES ARE RUN TO BUILDINGS ON OPPOSITE SIDE OF STREET FROM CABLE RUN.
8-INCHES
73.183

Figure 12-20.—Connecting drop wire to a terminal box.

insulation from the drop wire, so there will be no risk of a bare conductor touching an adjacent post; make one conductor of the drop wire slightly shorter than the other, to accommodate the post positions; and make sure the conductors are wound around the posts in the same direction as that in which the nuts tighten.

At the pole, you will have to attach the tracer conductor of the drop wire to the ring line, and the plain conductor to the tip line. The tracer conductor must always be connected to the RIGHT-SIDE binding post, to ensure that the connections are made correctly. This is also standard procedure in making connections at the protectors and at the connecting blocks; that is, always connect the gracer wire to the right-hand terminals.

At the central office the positive side of the battery is permanently grounded. This makes the negative or tracer wire a hot wire, and it must therefore be readily identifiable at all points for purposes of testing and repair. In a twisted-pair drop wire the outer covering often has a raised thread to identify the tracer wire. In parallel-drop wire the conductor with the ridged insulation is the tracer wire. In the inside wiring the wire with a red thread is the tracer.

HOOKING UP A HANDSET

A telephone set is practically a self-contained unit. In a desk or table set, the base contains ringer, induction coil, condensers, and hook switch. The transmitter and receiver are contained in the handset. Installing the set simply involves connecting the terminal lugs of the telephone cord to the block.

CHECKING AN INSTALLATION

As soon as a telephone is hooked up, check to ensure that connection to the proper line has been made. Then have someone ring back from the switchboard, to check the bell circuit. Check for satisfactory strength and quality of voice transmission.

BELLS AND BUZZERS

Where there are several telephones at a station, all working from one or two incoming lines, bells and buzzers will be a great convenience. To energize a bell circuit, you will need a low-voltage source—either dry cells or a bell transformer connected to a lighting circuit. You will require a pushbutton to make and break the bell circuit, a signaling device, and a wire to connect these components.

Mount a bell at each telephone. There should be a pushbutton for each bell, but these buttons should be located together at the central telephone location. Connect the transformer to the lighting circuit at any convenient point.

Use No. 18 wire for the bell circuit. This wire is attached to the secondary side of the transformer. One conductor is trained directly over to the bell; the other connects with the pushbutton. Another wire runs from bell to pushbutton, being connected at the screw terminals of each of these components.

FIELD TELEPHONE SYSTEMS

A field set is a telephone system designed for easy transportation from one location to another, and for rapid installation. Navy field set components include central office sets, distribution systems, and station equipment, capable of serving small, medium, or large bases. Because the SEABEES use a considerable amount of Army equipment, brief descriptions will be given of some of the commonly used Army field sets you may need to install and operate.

TC-2 SET

The TC-2 set is a central office set with the receivers mounted in the headband. It consists of a combination of local and common batteries, switchboard, main distributing frame, power unit, power panel, rectifier, and accessories. The switchboard has 57 circuit lines and 3 trunklines for connections to other switchboards.

The power unit is a self-contained 2500-watt a-c generating set, driven by a gasoline engine, and producing 120-volt single-phase 60-hertz current. The panel contains a voltmeter and ammeter for use in controlling the rate of charge of the storage batteries. A rectifier capable of charging the batteries at a maximum rate of 12 amperes is installed to change the alternating current to direct current.

The components of this set can be easily damaged, and care must therefore be exercised in unpacking. When installing, locate the switchboard as far away as possible from any source of excessive noise.

Figure 12-21 shows an interconnecting diagram of a TC-2 set. Cords may be small, flexible insulated cables or stranded wires,

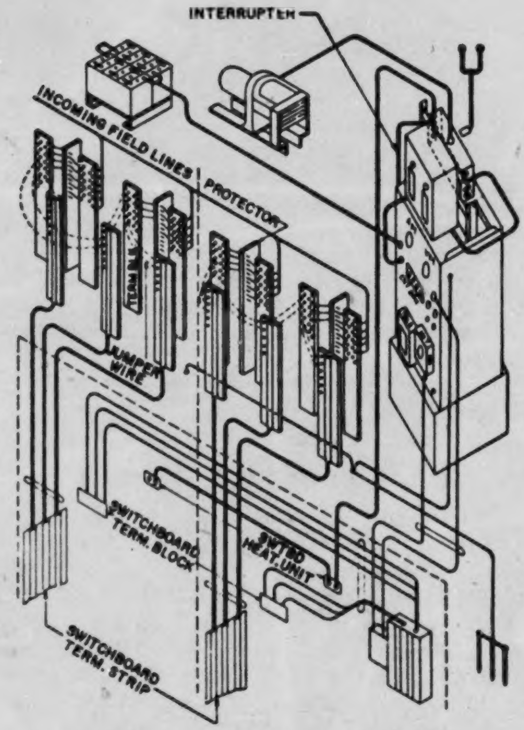

INTERRUPTER
INCOMING FIELD LINES
PROTECTOR
TERM BLK
JUMPER WIRE
SWITCHBOARD TERM. BLOCK
SWTBD HEAT UNIT
SWITCHBOARD TERM. STRIP

Figure 12-21.—Interconnecting diagram of a TC-2 central office set. 26.118

MANUAL TELEPHONE CENTRAL OFFICE AN/TTC-7A

The AN/TTC-7A is a transportable telephone central office (central office set) which basically can handle 200 local lines, 20 plug supervision trunks, and 20 manual or dial trunks. If the set is used to terminate incoming manual dial or trunks from another AN/TTC-7A, 20 of the line circuits must be used for termination. When not being used as terminators, the line circuits can be set up for either 200 common battery (CB) lines or 100 CB lines and any combination of 100 local battery (LB) and CB lines.

The basic AN/TTC-7A installation can be modified to handle up to 960 lines, 100 plug supervision trunks and 100 manual or dial trunks by the installation of additional components.

The main components of the AN/TTC-7A are shown in figure 12-22. The location of the units is limited only by the length of the interconnecting cables (these come in set lengths) and the amount of space in which the set is to be installed.

FIELD SWITCHBOARD SB-22A/PT

The SB-22A/PT is a lightweight field type, local-battery switchboard. Figure 12-23 names the main parts. The set is a self-contained unit, and requires no special mounting equipment for operation.

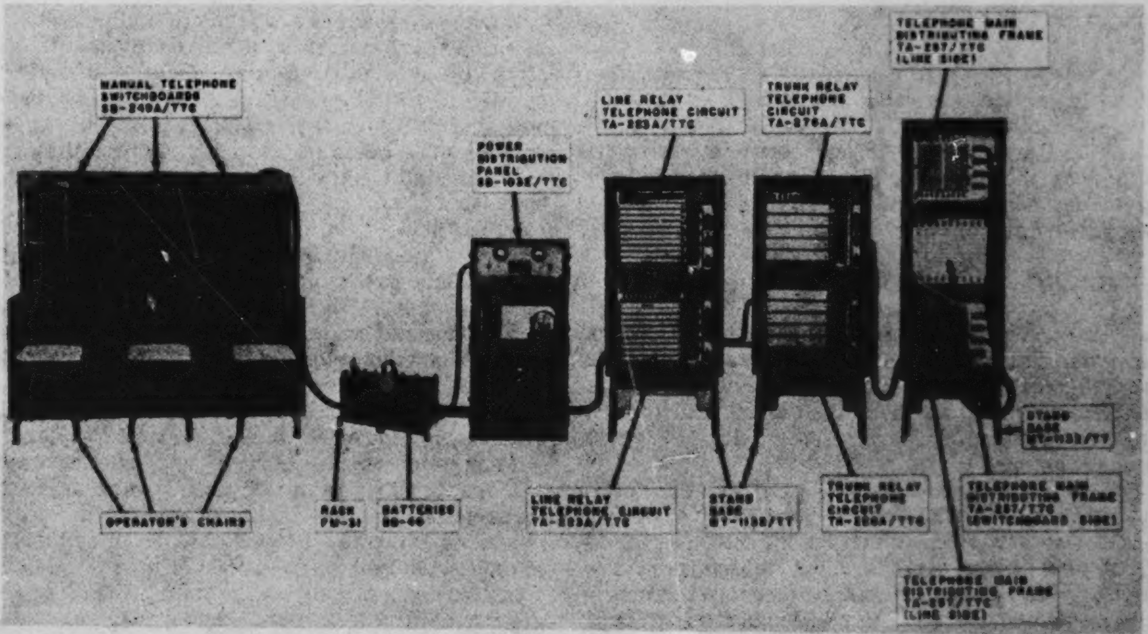
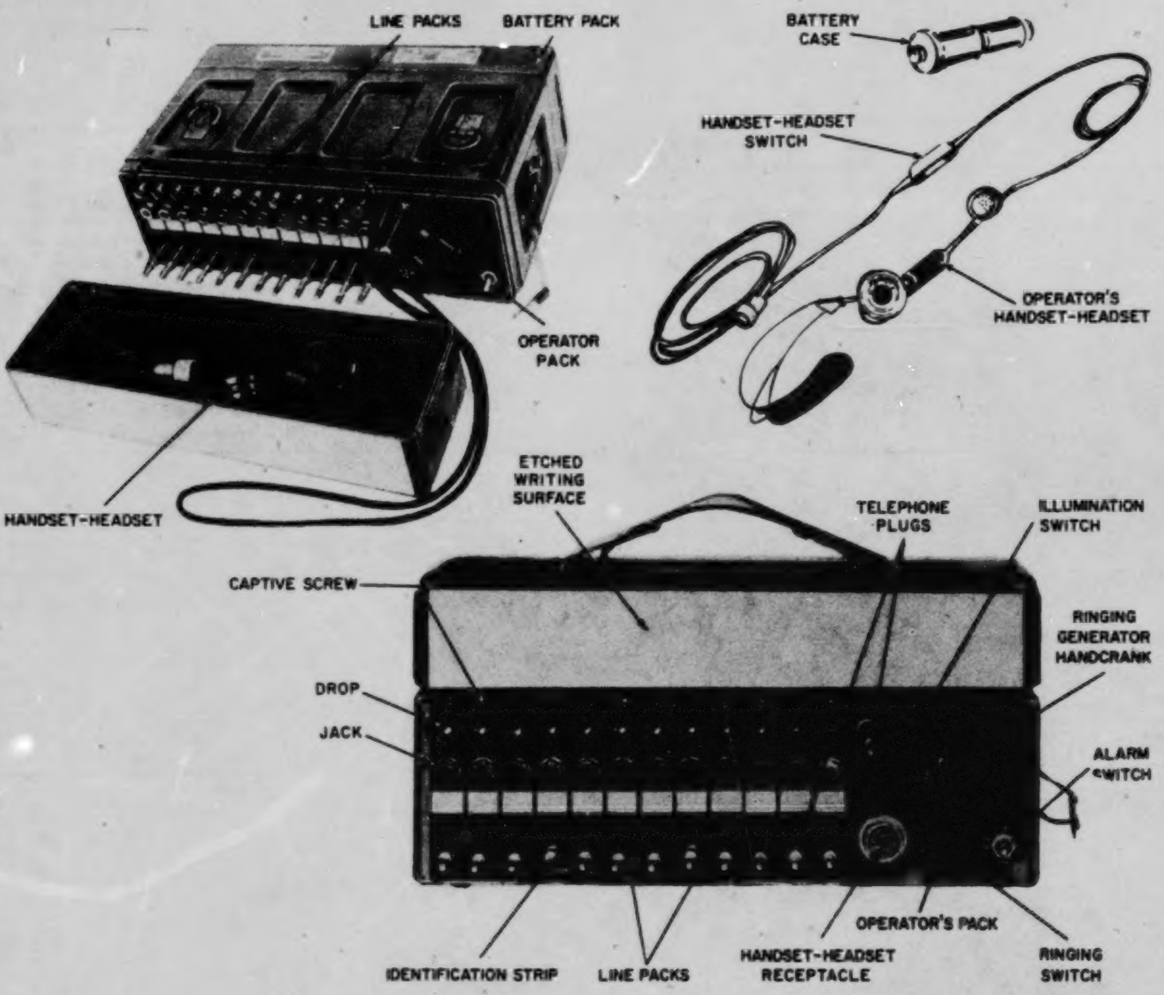

MANUAL TELEPHONE SWITCHBOARDS SB-240A/TTC
POWER DISTRIBUTION PANEL SB-103E/TTC
LINE RELAY TELEPHONE CIRCUIT TA-283A/TTC
TRUNK RELAY TELEPHONE CIRCUIT TA-276A/TTC
TELEPHONE MAIN DISTRIBUTING FRAME TA-257/TTC (LINE SIDE)
STAND BASE MT-1132/TT
OPERATOR'S CHAIRS
RACK FM-31
BATTERIES BB-46
LINE RELAY TELEPHONE CIRCUIT TA-283A/TTC
STAND BASE MT-1132/TT
TRUNK RELAY TELEPHONE CIRCUIT TA-286A/TTC
TELEPHONE MAIN DISTRIBUTING FRAME TA-257/TTC (SWITCHBOARD SIDE)
TELEPHONE MAIN DISTRIBUTING FRAME TA-257/TTC (LINE SIDE)

Figure 12-22.—Manual telephone central office AN/TTC-7A, main components. 26.268


LINE PACKS
BATTERY PACK
BATTERY CASE
HANDSET-HEADSET SWITCH
OPERATOR'S HANDSET-HEADSET
OPERATOR PACK
HANDSET-HEADSET
ETCHED WRITING SURFACE
TELEPHONE PLUGS
ILLUMINATION SWITCH
CAPTIVE SCREW
RINGING GENERATOR HANDCRANK
DROP
JACK
ALARM SWITCH
OPERATOR'S PACK
IDENTIFICATION STRIP
LINE PACKS
HANDSET-HEADSET RECEPTACLE
RINGING SWITCH

26.104

Figure 12-23.—SB-22A/PT manual telephone switchboard.

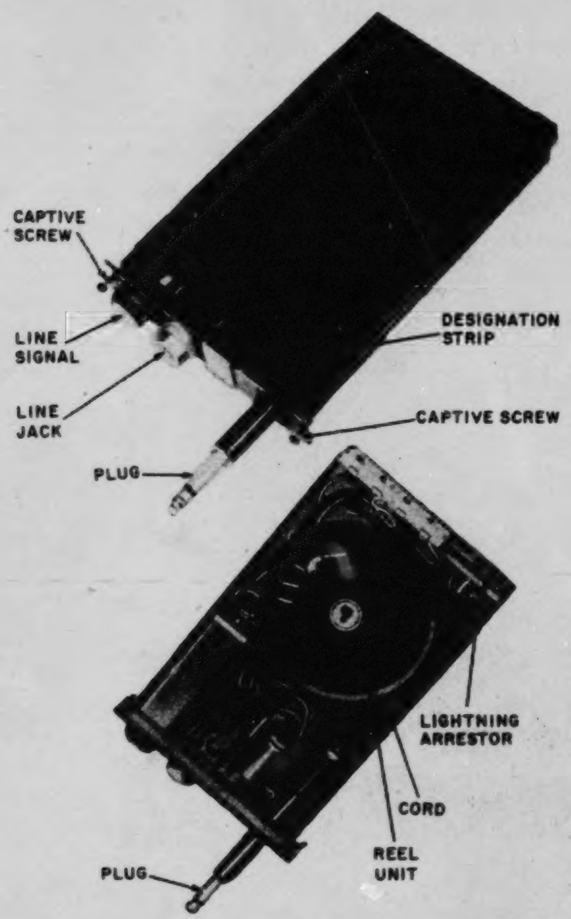
The switchboard is comprised of four major components. Three components make up the actual switchboard (the line pack, operator pack, and battery pack). The other component is the handset-headset.

The switchboard is designed to establish a working telephone system for units up to and including battalion size. The SB-22A/PT can be used for interconnection up to twelve local-battery lines and for remote control radio communications. It may also be intertrunked with a common-battery (CB) switchboard.

Under normal conditions, you will be concerned with only the telephone lines. The procedure for connecting the wires of the switchboard to a radio circuit is very similar to the procedure for making connections to the telephone circuit.

Line Packs

The 12 line packs are located on the left side of the front panel. A line pack is shown in figure 12-24. Each line pack is fastened to the switchboard by two captive screws, one at the



26.105

Figure 12-24.—Line pack.

top of the unit, and the other at the bottom. The line pack contains a reel unit, a line signal, a jack, an identification strip, and a lightning arrestor.

The REEL UNIT consists of a reel, a cord, and a plug. The cord is fastened to the spring-loaded reel by three screws at one end and is equipped with a standard switchboard plug at the other end. The cord may be extended to a maximum distance of 35 inches and is retracted by the spring-loaded reel.

The LINE SIGNAL consists of a plastic ball (indicator) with a permanent magnet embedded in it. The black plastic ball has a white strip around it. The magnet is embedded in part of this strip (fig. 12-25). When a telephone user turns the crank of the hand generator serving the telephone, a circuit is completed, setting up a magnetic field in the armature of the line signal indicator which attracts the magnet. The magnet aligns itself with the core, and the indicator shows white. When the line signal shows white and the operator inserts the operator's cord plug into the associated line jack, the ball is mechanically restored to show black.

The JACK is used in conjunction with the cord of the operator's pack, or with cords of the line pack, to interconnect line circuits.

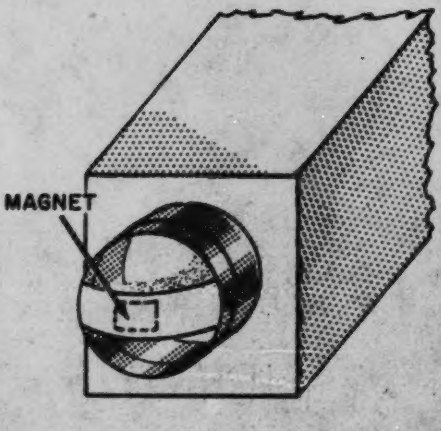
The IDENTIFICATION STRIP is a piece of white plastic fastened beneath the line jack. Marks on this strip identify the telephone circuit associated with the line pack.

A LIGHTNING ARRESTOR is provided for protection of the line from outside voltages.

Operator's Pack

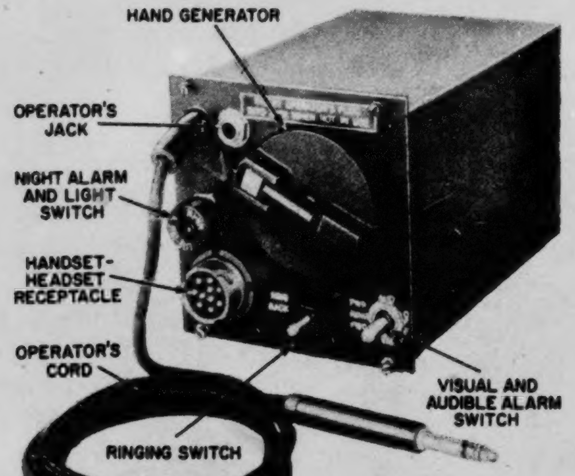
The operator's pack (fig. 12-26) is located on the right of the front panel. The pack consists of a reel unit, ringing equipment, alarm equipment, and a handset-headset receptacle.

The REEL UNIT is identical to that of the line pack. The ringing equipment consists of a

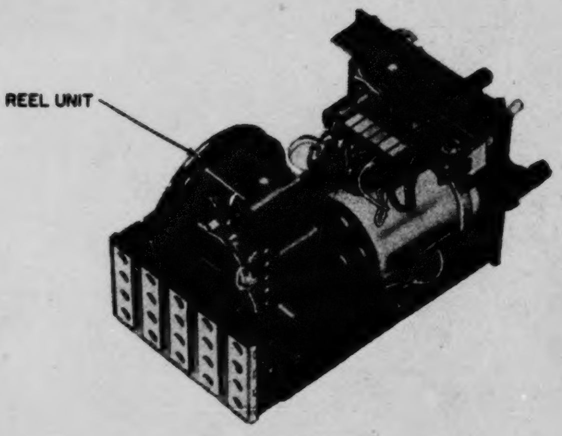


26.266

Figure 12-25.—Line signal indicator (with indicator lens removed).


HAND GENERATOR
OPERATOR'S JACK
NIGHT ALARM AND LIGHT SWITCH
HANDSET-HEADSET RECEPTACLE
OPERATOR'S CORD
VISUAL AND AUDIBLE ALARM SWITCH
RINGING SWITCH

EXTERIOR



INTERIOR

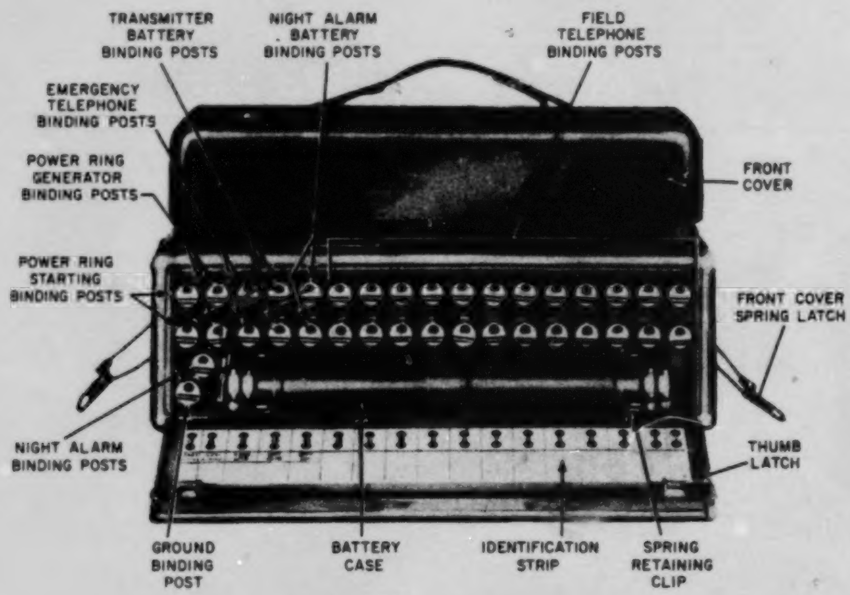
26.106

Figure 12-26.—Operator's pack.

hand generator and a control switch. Ringing current is generated when the handcrank is rotated. The control switch has two positions: RING BACK and PWR RING FWD. This switch enables the operator to connect ringing current to the calling or to the called telephone.

The ALARM EQUIPMENT provides a more positive signal for the operator than that afforded by the drop mechanism of the line pack. The alarm equipment consists of the signaling buzzer and a lamp. When the switchboard is signaled by an outlying telephone, the drop on the line pack associated with the outlying field telephone falls; this completes a circuit through the alarm lamp or the buzzer. Depending on the setting of the switch, either the lamp lights or the buzzer sounds.

The HANDSET-HEADSET receptacle is a polarized, bayonet-locking, 10-conductor receptacle


TRANSMITTER BATTERY BINDING POSTS
NIGHT ALARM BATTERY BINDING POSTS
FIELD TELEPHONE BINDING POSTS
EMERGENCY TELEPHONE BINDING POSTS
POWER RING GENERATOR BINDING POSTS
FRONT COVER
POWER RING STARTING BINDING POSTS
FRONT COVER SPRING LATCH
NIGHT ALARM BINDING POSTS
THUMB LATCH
GROUND BINDING POST
BATTERY CASE
IDENTIFICATION STRIP
SPRING RETAINING CLIP

26.104.2

Figure 12-27.—Rear view of switchboard, SB-22A/PT.

which is used with the plug on the handset-headset cord.

Battery Pack

The battery pack is located under the rear cover of the switchboard (fig. 12-27). It holds four BA-30 batteries which supply power to operate the set.

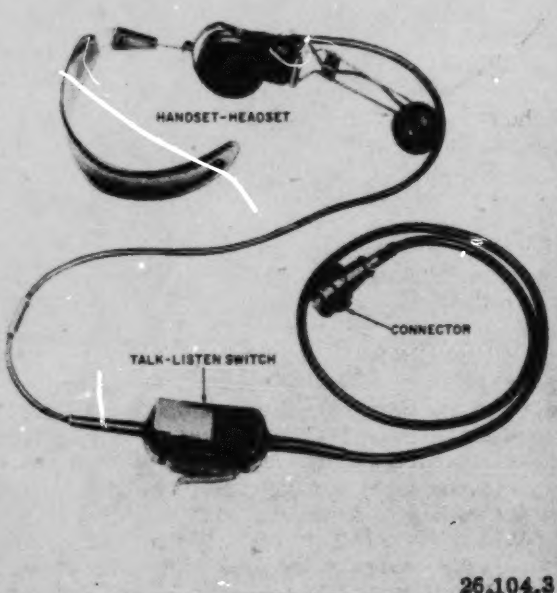
Handset-Headset

As illustrated in figure 12-28, the handset-headset consists of the actual handset-headset, the talk-listen switch, and the 10-conductor plug for connection to the operator's pack.

Unpacking

You should instruct your crew to be careful in unpacking the equipment. Immediately upon unpacking, you should have it inspected for possible damage during shipment.

The original packing cases and containers should be saved, so that they can be used again


HANDSET-HEADSET
CONNECTOR
TALK-LISTEN SWITCH

26.104.3

Figure 12-28.—Handset-headset.

when the equipment is repacked for storage or shipment.

Connecting Procedures

The ground connection should be made before connecting the wire lines to the switchboard. Select the lowest, dampest site in the vicinity; clay or loamy soil is best. Scoop out a hole 6 inches deep and drive a ground rod into the hole until the top of the rod is about 3 inches below the undisturbed ground surface. Connect one end of the wire to the ground rod. The earth around the rod should be saturated with water, and the hole filled with earth. Now connect the other end of the wire to the ground binding post (fig. 12-27) located on the frame behind the rear access door.

To connect the wire lines to the switchboard, a pair of binding posts should be selected and connected to the desired circuit. Be sure to record the circuit identification on the proper identification strip.

When the wire lines are connected, you are ready to install the four dry cell batteries. Remove the battery case and insert two batteries into the compartment so that the brass contact end of each battery faces outward. Repeat the procedure for the compartment at the other end of the battery case. After completing this operation, replace the case into the spring retaining clips.

After the connections are made, talk over the line and note the quality of transmission. If transmission is poor or speech cannot be heard at normal speech level, check the connection wiring. If the trouble continues, replace the operator's pack and check again.

Stacking of Two Switchboards

To serve more than 12 but fewer than 30 lines, stack the 12-line switchboards. Remove the operator's pack from the switchboard and install five line packs in the empty space. This modified switchboard should be placed on top of a normally equipped switchboard. Use two jumpers to connect the two switchboards. One jumper must be connected to the NA binding posts of both switchboards, and the other jumper must be connected to the GND binding posts of both switchboards. Be sure that the jumpers pass through the slot at the side of each switchboard. Only one set of batteries is required to serve both switchboards; the battery case from the one containing the 17 line packs (from which the operator's pack has been removed) should be removed. The field telephones can then be connected. A maximum of 29 lines can be served with this arrangement as shown in figure 12-29.

Maintenance and Repair

See that your crew makes frequent inspections of the equipment to keep it in good working order. Dust, dirt, grease, or moisture should not be allowed on the exterior of the switchboard or the handset-headset. A clean, dry, lint-free cloth or a dry brush should be used for cleaning. The electrical contacts on the frame of the switchboard should be cleaned with a cloth moistened with drycleaning solvent, and should be wiped dry with a clean dry cloth. A burnishing tool should be used to clean the switch contacts.

Rust, fungus, dirt, and moisture tend to accumulate on the binding posts, plugs, and external portions of the line jacks. Have these removed with a dry rag or brush. The battery case and clip contacts should be inspected for corrosion, moisture, fungus, and tightness. All lines should be checked for kinks, strains, moisture, fungus, and loose terminals; also have the insulation checked to see that it is not frayed, cut, or otherwise damaged.

Normally moving parts of the SB-22A/PT do not require lubrication. When necessary, lubricate the spring latches of the front cover, and the thumb latches and hinge of the rear access door.

Failure of the switchboard to operate properly is usually caused by one or more of the following:

1. Rundown batteries
2. Defective operator's handset-headset
3. Defective line pack
4. Defective operator's pack

Rundown batteries may be indicated by any of these difficulties:

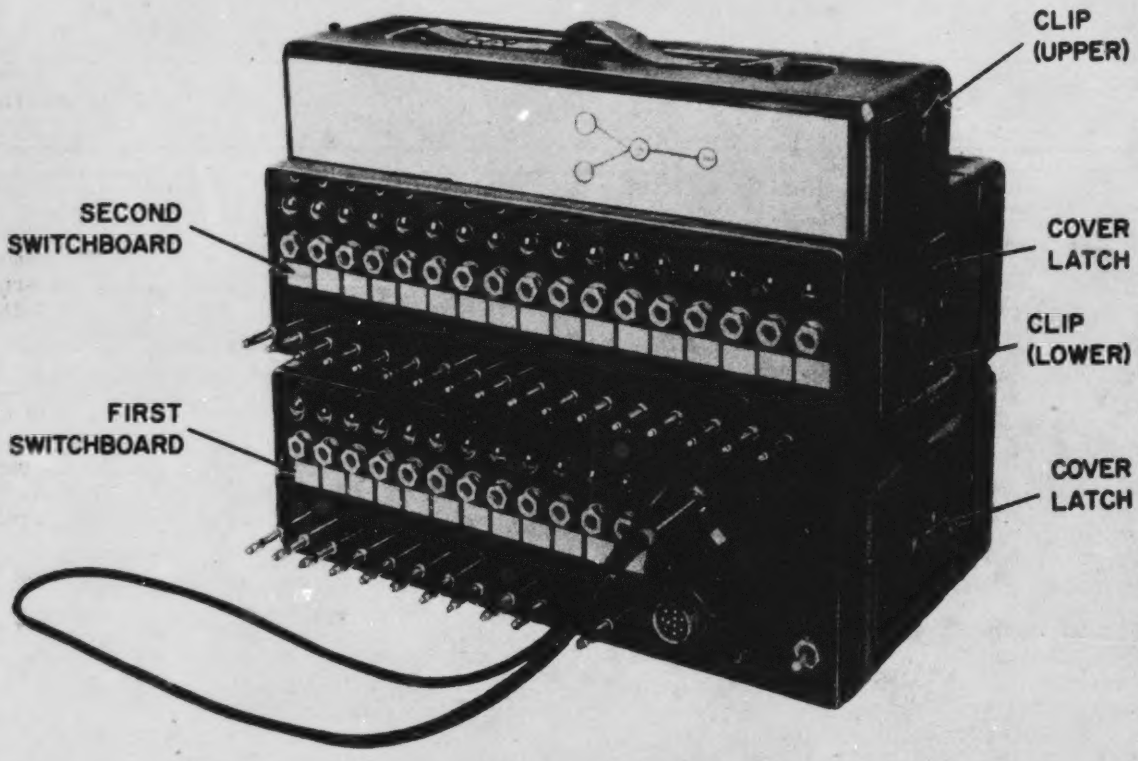
1. Pull switch is pulled out, but lamp fails to light.

2. Drop of a line pack indicated that a telephone is signaling the switchboard, but the lamp or buzzer of the operator's alarm fails to work.

3. The operator cannot talk to any of the telephone users.

Remove rundown batteries, and replace them in the manner previously described.

A defective handset-headset prevents the operator from talking to any of the telephone users, from receiving calls from any of the



26.267

Figure 12-29.—Installation arrangement for two switchboards.

outlying phones, or both. Replace defective handset with one that is in working order.

A defective line pack may be indicated by any of the following troubles:

1. The user of a telephone cannot signal the operator because the drop does not function.
2. The drop of a line pack for a particular telephone works, but the operator's alarm fails to function. (If this difficulty occurs with all telephones, the trouble may be rundown batteries or a defective operator's pack.)
3. The operator cannot talk to or receive calls from the user of a telephone.
4. The users of two telephones cannot converse with each other, but the operator can converse with each user separately.

The line pack is a self-contained, plug-in unit. It may be removed by loosening the two captive screws from the front panel, inserting the plug into the jack, and pulling on the plug until the line pack is free from the front panel. The replacement should then be inserted. After the two captive screws are tightened, the new line pack is ready for operation.

A defective operator's pack may be indicated by any of the following difficulties:

1. Lamp fails to light when a pull switch is pulled out (also may be caused by burned-out lamp or rundown batteries).
2. The operator's alarm fails to work when the drop of a line pack indicates that a telephone is signaling the switchboard (may also be caused by rundown batteries).
3. The operator cannot ring any field telephone.
4. The operator cannot talk to any telephone users (may also be caused by a defective handset-headset or rundown batteries).

5. The operator cannot receive calls from telephones on the line (may also be caused by a defective handset-headset).

6. The operator cannot ring back.

The operator's pack is also a self-contained plug-in unit. A replacement is ready for operation after installation of the unit and tightening of the four captive screws.

If at all possible, you should always have handy a circuit wiring diagram and exploded views of the various parts of the SB22A/PT switchboard, in order to make emergency repairs.

FIELD TELEPHONE TA-312/PT

The TA-312/PT field telephone (fig. 12-30) is a versatile phone for use in manually operated two-wire CB or LB field systems. It can be used either outdoors (regardless of weather conditions) or inside as a desk or wall phone. Besides being used as a phone it can control remote control radio equipment.

Functions

The unit is self-contained, requiring two internal batteries or an external 3-volt a-c source (which is connected to the external battery terminals) for operation.

The set is designed to allow the handset to hang in the housing panel (handset retaining bracket) when not in use. When the handset is in the retaining bracket, the line switch disconnects the internal battery. A receptacle connector is provided for use of an external handset/headset (fig. 12-28). The EXT-INT switch determines which handset is used.

The phone can be used in three modes as selected by the CIRCUIT SELECTOR switch: CB talking and signaling, LB talking, and CB signaling. A buzzer is included for signaling from another set. The buzzer volume is controlled by the BUZZER VOLUME control. To signal another set, the hand generator crank must be manually turned.

The binding posts are used for hooking to another set or a switchboard.

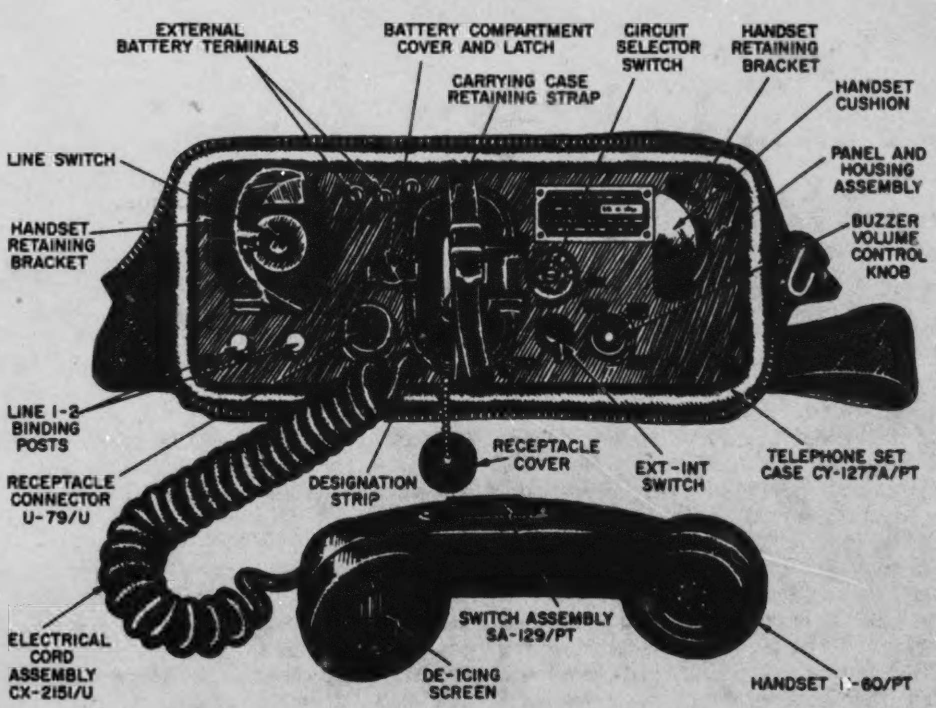

EXTERNAL BATTERY TERMINALS
BATTERY COMPARTMENT COVER AND LATCH
CIRCUIT SELECTOR SWITCH
HANDSET RETAINING BRACKET
CARRYING CASE RETAINING STRAP
HANDSET CUSHION
LINE SWITCH
PANEL AND HOUSING ASSEMBLY
HANDSET RETAINING BRACKET
BUZZER VOLUME CONTROL KNOB
LINE 1-2 BINDING POSTS
RECEPTACLE COVER
RECEPTACLE CONNECTOR U-79/U
DESIGNATION STRIP
EXT-INT SWITCH
TELEPHONE SET CASE CY-1277A/PT
SWITCH ASSEMBLY SA-129/PT
ELECTRICAL CORD ASSEMBLY CX-2151/U
DE-ICING SCREEN
HANDSET H-60/PT
73.185

Figure 12-30.—TA-312/PT set.

Maintenance

Maintenance is divided into two types: operation and shop.

Operator's maintenance is performed daily and consists of cleaning all exterior surfaces with a lint-free cloth moistened with an approved cleaning solvent, checking the handset switch assembly for proper mechanical action (binding, scraping, looseness), and a normal operator's check (talk, receive, buzzing and buzzer).

Shop maintenance is performed weekly, and as such, is more extensive. Included are inspecting the external finish, cords, housing, carrying case, binding posts, and battery compartment for breaks, cracks, cuts, frays, fungus, dirt, moisture, corrosion, or general deterioration. The handset is also checked for loose receiver or transmitter elements.

The panel should not be removed nor the handset disassembled unless the maintenance checks indicate a malfunction of internal parts.

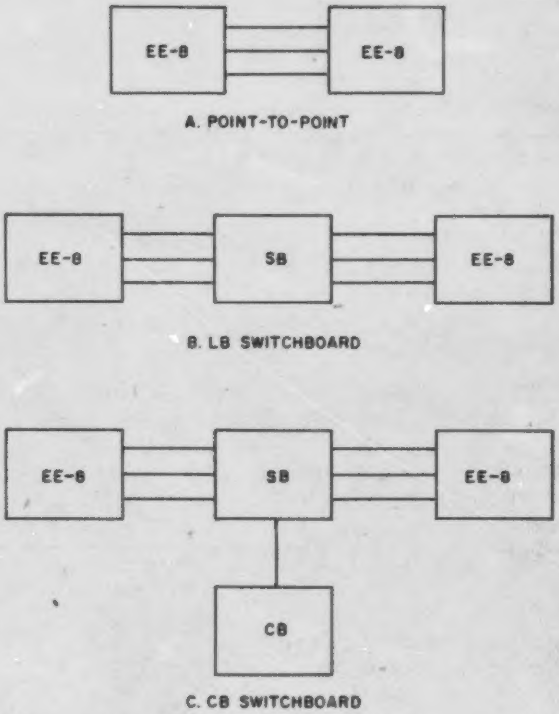
TELEPHONE EE-8

Telephone EE-8 is designed for use in point-to-point circuits and LB or CB switchboard systems. Depending upon the type of wire lines used, the range for point-to-point circuits is anywhere from 4.5 to 360 miles and in switchboard systems, the range varies from 0.9 to 72 miles.

Operation

Figure 12-31 diagrams the hookup for different uses. Figure 12-31, view A is a point-to-point circuit Note that the telephones at both ends of the circuit are connected without intervening switchboards. Local batteries are used and the hand generator (a part of the telephone) is used for signaling.

Figure 12-31, view B (LB switchboard system) has the telephones set up through an LB switchboard to enable circuits to be set up between any telephone in the system. In this case, as in point-to-point circuits, local batteries are used and the hand generator is still used for signaling. The advantage over point-to-point systems is that several switchboards may be trunked together for a greater number of stations. The disadvantage is loss of talking range. (The ratio of range switchboard systems to point-to-point circuits is approximately 1:5 with trunked switchboards, or 1:2 using only one switchboard.)



26.288

Figure 12-31.—Telephone EE-8 system hookup.

CB switchboard systems (fig. 12-31, view C) use the common battery for signaling, though local batteries are still used for transmission. In this case, the hand generator is not used as the telephone lever switch is used to signal the switchboard operator.

Maintenance

In general, the same maintenance requirements prescribed earlier for the field switchboard apply here—inspect, tighten, clean and adjust. Since these sets are used outdoors, there are a few extra requirements. For instance, such things as dust, rapid weather changes, and excessive dampness all require more meticulous maintenance to keep the equipment dependable.

In addition, batteries will begin to deteriorate in as short a time as 48 hours with the handset switch left in the operate position. Even batteries in a stored telephone, with the switch in the OFF position, will begin to deteriorate in time, due to the physical breakdown of the battery caused by the pressure of the contact springs. Consequently, the handset switch must be turned off when not in use, and the batteries must be removed when the telephone is to be stored for any length of time.

AUTOMATIC TELEPHONE SYSTEM

All telephone systems in use at the present time fall into two categories: NONDIAL (MANUAL) SYSTEMS and DIAL SYSTEMS. Dial telephone systems are also called MACHINE-SWITCHING or AUTOMATIC SYSTEMS.

Any telephone system consists of a group of telephones with lines terminating at a central point (switchboard or central office) in such a way that any two telephones in the system may be connected with one another. A nondial or manual system is one in which connections must be made by hand by an operator. In a dial system connection is made automatically by means of electromechanically operated switching mechanisms remotely controlled by a dial, or calling device, at the telephone initiating the call.

There are two types of automatic dial telephone systems: the step-by-step type, which utilizes electromechanical switches to find and connect the number being called; and the relay system, which utilizes only the closing of electrical contacts to connect the lines in the system.

A step-by-step type may be expanded to handle a larger number of lines by simply adding additional equipment. An all-relay system is limited to the number of lines for which the unit is designed. Most of the dial installations used by the Armed Forces are of the step-by-step type. Some small installations use the all-relay system, but these are usually systems with not more than 100 lines.

The commonly used step-by-step dial central office is usually a 2-wire, 46- to 52-volt common-battery, fully automatic type telephone system. Two-wire means that no matter how many wires are used between units of switching equipment inside the central office, only two wires extend between the central office and the telephone served by it. The two wires may be enclosed in a cable to form a cable pair. They may be a twisted insulated-wire pair, or they may be two bare wires on insulators. The term "46- to 52-volt common-battery" refers to the source of electrical energy provided at the central office to operate the automatic equipment, and to supply transmission (talking) and signaling (ringing) current to the outside telephone lines. The voltage range indicated means that the equipment will operate efficiently over a range of from 46 to 52 volts, direct current.

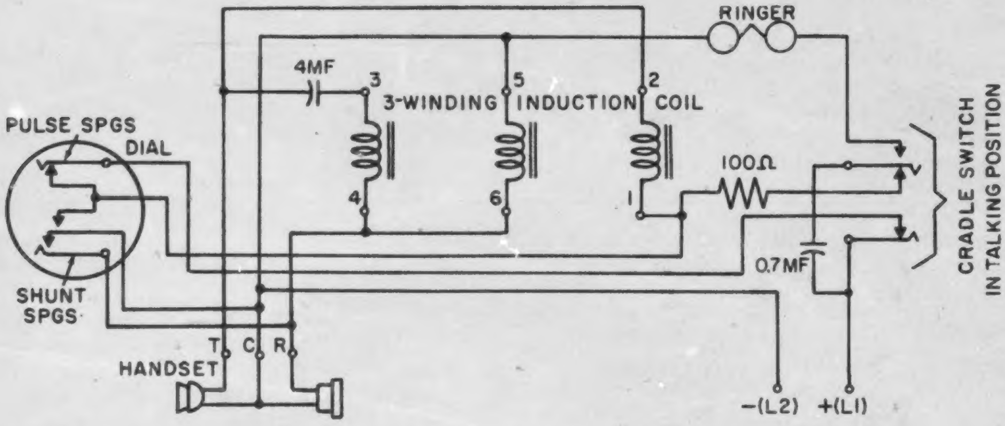
The switching equipment in a step-by step dial central office operates directly from dial pulses transmitted from the pulse-sending device, or dial, of the calling telephone. The dial pulses are interruptions of current caused by the alternate opening and closing of pulse springs in the dial mechanism. Figure 12-32 shows the circuit of a typical dial telephone with the contacts in talking position. Figure 12-33 shows front and rear views of a typical dial.

In a step-by-step dial telephone system each set, or series, of dial pulses (sometimes called train of pulses or pulse train) corresponding to each digit dialed by the telephone users extends a connection one step at a time through the switching equipment to the called telephone. The wipers, or contacting arms, of numerical (dial controlled) stepping switches establish the proper connections at the central office. These wipers are moved one step at a time by electromagnets operated by pulses from the dial of the calling telephone. This is how the step-by-step dial telephone derives its name.

Figure 12-34 shows a step-by-step switchroom. The can-like containers house switching equipment consisting of two-motion Strowger switches (fig. 12-35).

STROWGER SWITCHES

The Strowger switch is an electromechanical product that extends the connection from the calling to the called telephone. It consists of a bank of electrical contacts arranged in 10 levels with 10 sets of contacts to a level. The wipers, which make contact with the selected


RINGER
4MF
3
5
2
3-WINDING INDUCTION COIL
PULSE SPGS
DIAL
4
6
1
100Ω
CRADLE SWITCH IN TALKING POSITION
0.7MF
SHUNT SPGS
T
C
R
HANDSET
-(L2)
+(L1)

73.186

Figure 12-32.—Circuit of representative dial telephone, talking position.

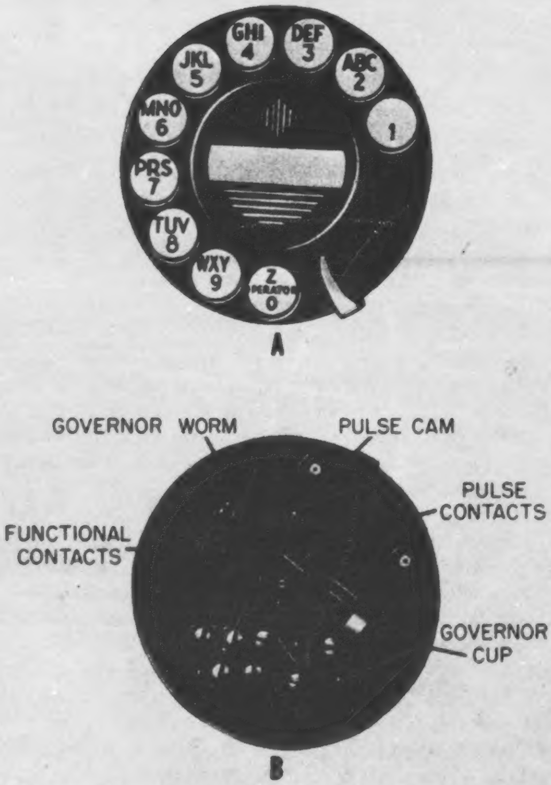
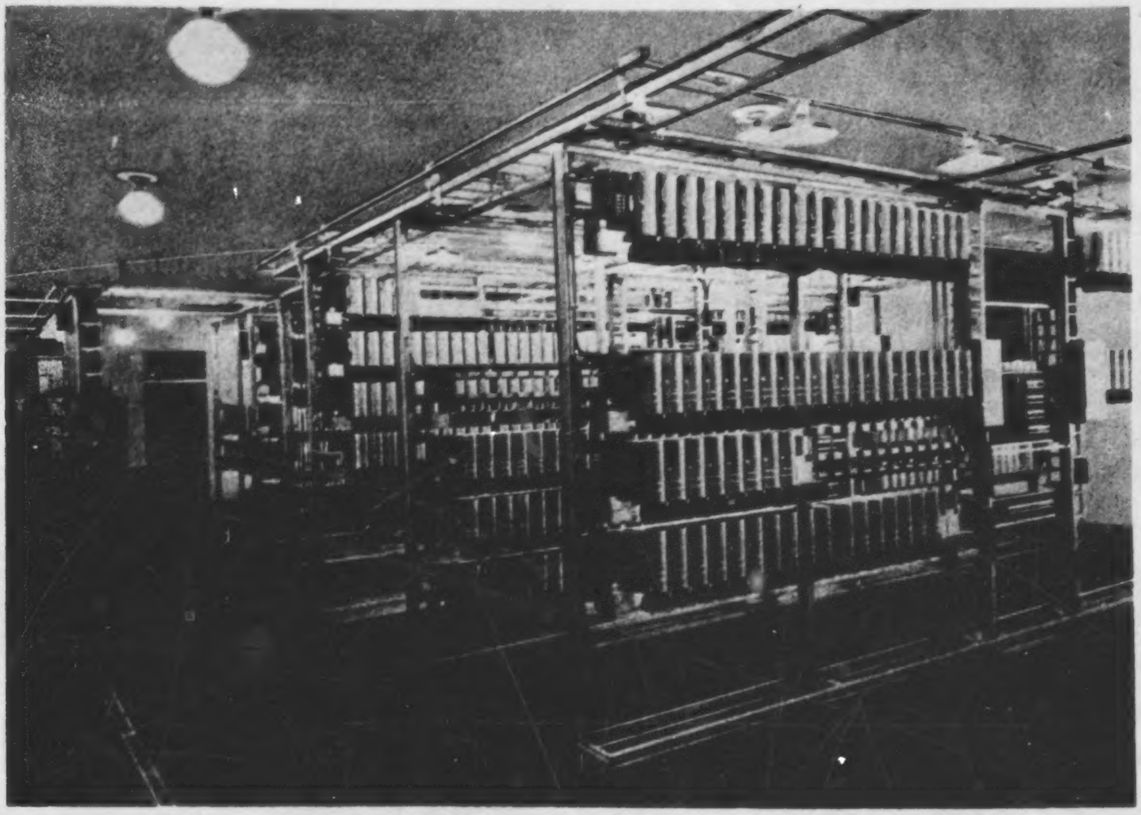

GHI 4
DEF 3
JKL 5
ABC 2
MNO 6
1
PRS 7
TUV 8
WXY 9
Z OPERATOR 0
A
GOVERNOR WORM
PULSE CAM
PULSE CONTACTS
FUNCTIONAL CONTACTS
GOVERNOR CUP
B

Figure 12-33.—Front and rear views of telephone dial. 7.85

set of contacts, are connected to the switch shaft. The switch mechanism elevates the shaft (and wipers) any number of steps from 1 to 10. When the shaft is released, it rotates backwards under the influence of a spring and then returns to normal under the pull of gravity. The Stowger switch, because of the up and around movement, is referred to as a two-motion or step-by-step switch. It is the basic switch of the step-by-step system, and with a few mechanical and electrical variations, is used as a linefinder, connector, and selector.

The LINEFINDER finds the line of the telephone station seeking to make a call and extends the line to the selector for all systems in excess of 100 lines. The linefinder mechanism is controlled by the finder control relays. The impulses to step the mechanism up and around are furnished by interrupter springs on the vertical and rotary magnets. The finder switch is referred to as a NONNUMERICAL type of Strowger switch, because its operation is automatic and not under the control of dial impulses. The linefinder switch depends on its associated line-and-cutoff relays, group control relays, and distributor relays.

The LINE-AND-CUTOFF RELAY is a relay individual to the line with which it is associated (in contrast to the switch circuits which serve many lines and the control circuits which serve many switches). For example, when a call is initiated by a telephone, the line-and-cutoff relay functions to: (1) apply ground (positive side of the battery) to start the linefinder control relays



73.187

Figure 12-34.—Step-by-step dial telephone switchroom.

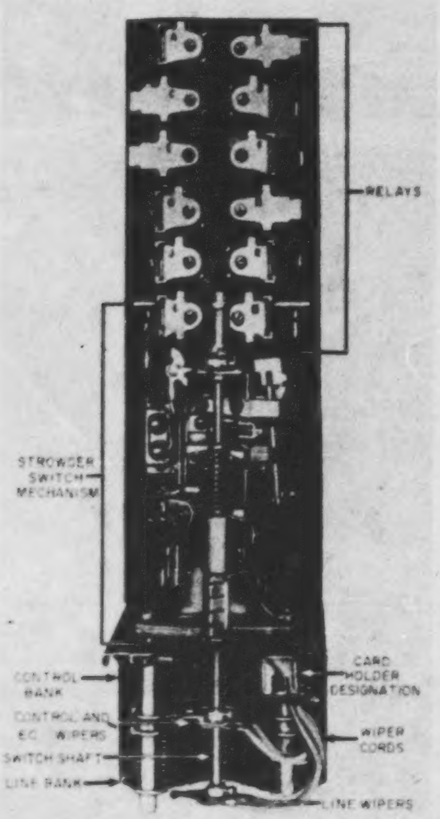
to actuate a linefinder switch to hunt for the calling line; (2) mark a contact in the bank of a linefinder by placing battery (negative voltage) on the contact so that when the linefinder wiper encounters battery the linefinder will know it has located the line it is trying to find.

The SELECTOR extends the line of the calling telephone to the connector. The vertical stepping of the selector is controlled by the first digit dialed at the calling telephone, and the rotary stepping is controlled by interrupter springs on the rotary magnet.

The CONNECTOR extends the line of the calling telephone to the line of the called telephone. The impulses transmitted from the dial of the calling telephone actuate the connector mechanism to step the wipers up and around to the set of contacts associated with the called telephone station. A connector switch is referred to as a NUMERICAL type of Strowger switch because it operates under the control of dial impulses.

The simplest arrangement for establishing a connection between two telephones consists of two elements, a linefinder and a connector, and is called a link. This combination performs satisfactorily in an exchange servicing less than 100 telephone lines. When additional lines are required, first, second, third, and so on, selectors are added. A group of links is called a bank.

Figure 12-36 shows a typical wiper and terminal bank for a two-motion stepping switch that operates vertically on the first operation and horizontally on the second operation.

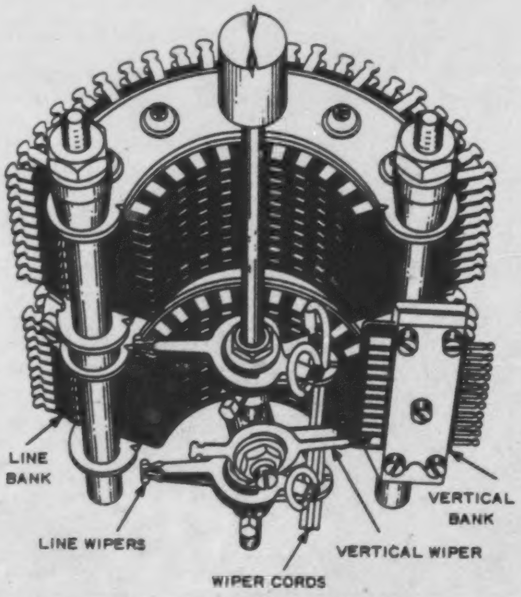


27.336
Figure 12-35.—Strowger switch.

100-LINE SYSTEM

Figure 12-37 shows a schematic diagram of two linefinder-connector links for a basic 100-line linefinder-connector system. One such link is required for each simultaneous conversation. For example, if the normal operation of the system shows an average of 20 simultaneous conversations, then 20 links are needed in the bank in order to handle all calls. Each link is like a cord circuit of a manual telephone system. Notice that the 100 lines (indicated by the lines numbered 44 and 75) are connected parallel to all linefinders as well as to all connectors in the bank.

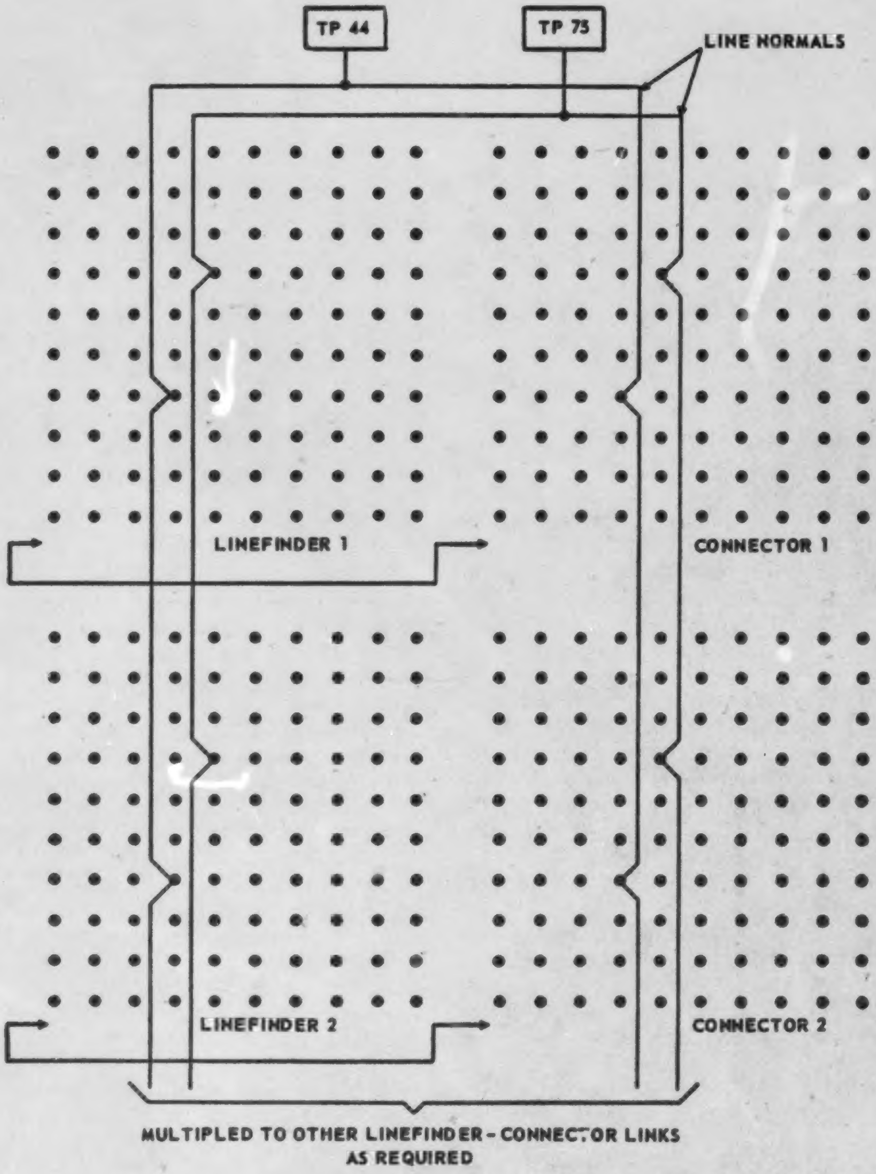
Since each of the 100 lines is connected in parallel to all of the linefinders in the bank, any idle linefinder in the system can automatically hunt for and find the line of any telephone in the system when the handset of that particular telephone is lifted from the cradle.



73.189
Figure 12-36.—Wipers and terminal bank.

Because each of the 100 lines of the system is also connected in parallel with each of the connectors in the bank, the connector linked with the linefinder can raise and rotate its wipers, under control of dial pulses from the calling telephone, to complete a connection to any one of the 99 other telephones in the 100-line basic linefinder-connector system. Notice that the leads from the connector banks back to the 100 lines of the linefinder bank are called line normals. Line normals are also called normals, normal wires, or normal cables.

To trace a typical call through the 100-line basic linefinder-connector system, assume that a telephone user at telephone No. 44 wishes to call telephone No. 75. When the handset of telephone No. 44 is lifted from the cradle, an idle linefinder (in this example linefinder No. 1) automatically elevates and rotates its wipers until they come to rest at contact set No. 44. The linefinder automatically extends the calling line through to the connector which is linked to the linefinder. The connector returns a dial tone to the calling telephone, to signal the user that the digits of the called telephone number


TP 44
TP 73
LINE NORMALS
LINEFINDER 1
CONNECTOR 1
LINEFINDER 2
CONNECTOR 2
MULTIPLED TO OTHER LINEFINDER - CONNECTOR LINKS AS REQUIRED

NOTES

1. ONLY TWO OF THE 100 TELEPHONE LINES ARE SHOWN ALTHOUGH EVERY ONE OF THE 100 LINES HAS A MULTIPLE APPEARANCE AT THE BANKS OF EACH LINEFINDER AND CONNECTOR IN A LINK.
2. ONLY TWO LINEFINDER - CONNECTOR LINKS ARE SHOWN. EACH OF THE 100 LINES IS MULTIPLED SIMILARLY TO OTHER LINEFINDER - CONNECTOR LINKS AS REQUIRED.

7.80

Figure 12-37.—Linefinder-connector links.

(No. 75 in this example) may be dialed. When the digits 7 and 5 of the called telephone are dialed, the connector operates in response to the resulting pulses from the dial of the calling telephone and raises its wipers to the 7th contact level, and then rotates its wipers to the 5th contact, so that the wipers come to rest on bank contact No. 75.

The connection is then completed from calling telephone No. 44 through linefinder-connector link No. 1, and over the line normals of line No. 75 to telephone No. 75. The connector then tests called telephone No. 75. If the called telephone is idle (not in use) the connector transmits ringing-tone current over the called line to operate the ringer of the called telephone. If, however, the called telephone is in use, the connector transmits busy-tone current to the calling telephone to advise the caller that the called telephone is busy. The busy-tone signal advises the calling telephone user to replace the handset on the cradle, and to try to make the call again a few moments later.

1000-LINE SYSTEM

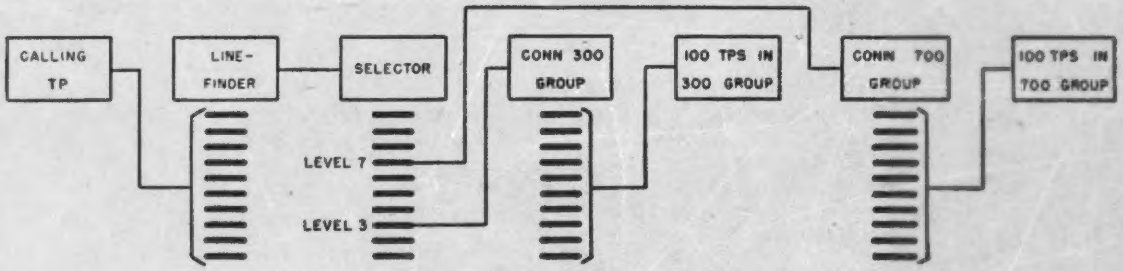
Systems with a capacity of more than 100 lines require the use of an additional two-motion stepping switch called a selector. The mechanical structure of a selector resembles that of a linefinder and a connector. The banks, the method of bank contact numbering, the wipers, and the two-motion stepping mechanism of a selector are practically the same as those of the linefinder and connector.

The selector is introduced in the switch train between the linefinder and the connector (fig. 12-38). The linefinder and the selector form the link. One such link is required for each conversation to be held. The linefinder searches for the calling line and extends it to the selector. The selector extends the calling line to a succeeding connector in the switch train. The connector, or last switch in the switch train, extends the calling line through to the called line, and the call is completed in the usual manner.

Unlike the linefinder but like the connector, the selector faces forward toward the called line. In a basic 1000-line system, the telephone lines are associated into 10 groups of 100 lines each. It is the function of the selector to select the group of 100 lines (hundreds group) in which the called line is located. The connector selects both the subgroup of 10 lines (tens group) in which the called line is located, and the particular line itself (unit line) in that group.

This straightforward 1000-line system requires telephone numbers containing three digits each, the selector operating in response to the pulses of the first number dialed and the connector responding to the following two numbers. A 1000-line central office thus has 10 connector groups, one for each hundreds group. Only two of the ten connector groups are shown in figure 12-38: the group of connectors that serves the 100 lines in the 300 group, and the group of connectors that serves the 100 lines in the 700 group. The term "300 group" refers to lines with telephone numbers from 300 to 399; the term "700 group" refers to lines with numbers from 700 to 799.

To illustrate the operation of the 1000-line system: assume that a telephone user at the calling telephone in figure 12-38 wants to call telephone number 344. When he removes the handset from the cradle, an idle linefinder hunts for and finds the calling line, and extends the



7.82

Figure 12-38.—Block diagram of 1000-line system, showing selector.

calling line to the selector linked to that specific linefinder. The selector, when grasped, returns a dial tone to the calling telephone user, who then dials first the digit 3 (the hundreds digit). Three pulses from the dial of the calling telephone cause the selector to raise its wipers to contact level 3. The selector then automatically rotates its wipers over the contacts on level 3, searching for a contact set (trunk) to which an idle connector in the 300 group is connected. The sets of wires from the selector to the connectors are called trunks. The automatic selection of an idle trunk is called trunk hunting.

Upon finding an idle trunk on the dialed level (3 level in this case), the call is extended by the selector through to the connector. When the digits 4 and 4 are dialed, the connector completes the call in the usual manner.

10,000-LINE SYSTEM

The procedure for a central office with a capacity of more than 1000 lines follows the same pattern as that for the 1000-line system, except that an additional selector is added in the line between the linefinders and the connectors. The first selector returns the dial tone, steps its wipers up to the dialed level under control of the first digit dialed (the thousands digit), and automatically rotates the wipers over the dialed level until they seize a trunk to an idle selector. The second selector elevates its wipers to the dialed level under control of the second digit dialed (the hundreds digit), and then automatically rotates the wipers until they seize a trunk to an idle connector. The connector completes the call in the usual manner. All this is illustrated in figure 12-39.

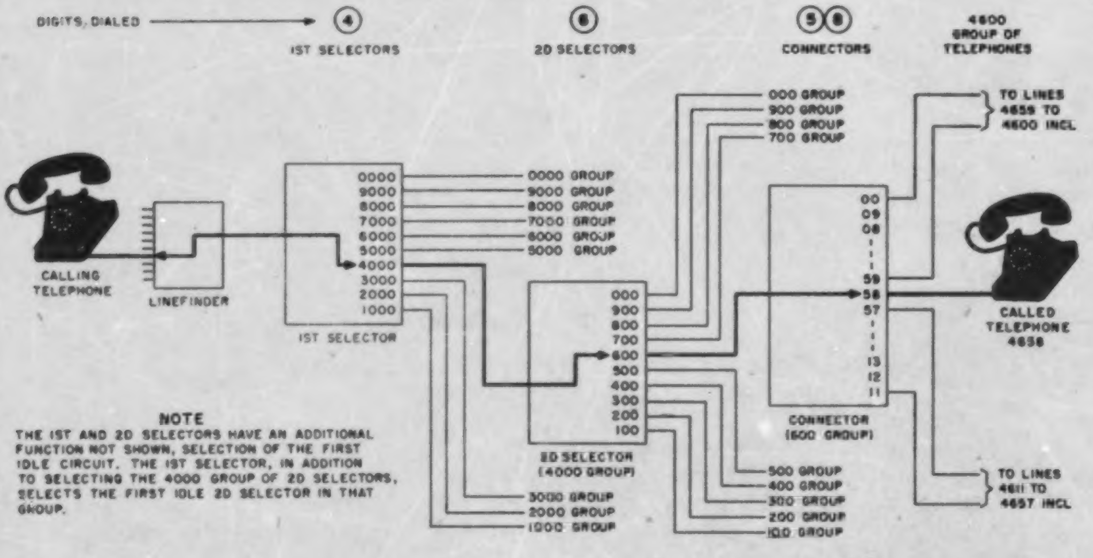
TROUBLESHOOTING

Tables 12-1 and 12-2 show common troubles, symptoms, and corrections in typical step-by-step dial central-office equipment.

CROSSBAR SWITCHING SYSTEM

The crossbar switching system has two main divisions of equipment, each with different functions. The two divisions of equipment are: the control equipment and the switching network.

The CONTROL EQUIPMENT establishes the talking path by causing the proper switch to operate. The SWITCHING NETWORK consists mostly of crossbar switches through which the talking paths are set up.


DIGITS, DIALED
④
1ST SELECTORS
⑥
2D SELECTORS
⑤⑧
CONNECTORS
4600 GROUP OF TELEPHONES
000 GROUP
900 GROUP
800 GROUP
700 GROUP
TO LINES 4659 TO 4600 INCL
0000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0000 GROUP
9000 GROUP
8000 GROUP
7000 GROUP
6000 GROUP
5000 GROUP
CALLING TELEPHONE
LINEFINDER
1ST SELECTOR
000
900
800
700
600
500
400
300
200
100
2D SELECTOR (4000 GROUP)
00
09
08
59
58
57
13
12
11
CONNECTOR (600 GROUP)
CALLED TELEPHONE 4658
500 GROUP
400 GROUP
300 GROUP
200 GROUP
100 GROUP
TO LINES 4611 TO 4657 INCL
3000 GROUP
2000 GROUP
1000 GROUP

NOTE
THE 1ST AND 2D SELECTORS HAVE AN ADDITIONAL FUNCTION NOT SHOWN, SELECTION OF THE FIRST IDLE CIRCUIT. THE 1ST SELECTOR, IN ADDITION TO SELECTING THE 4000 GROUP OF 2D SELECTORS, SELECTS THE FIRST IDLE 2D SELECTOR IN THAT GROUP.

73.190

Figure 12-39.—Simplified 4-digit dial system.

Table 12-1.—Troubles Indicated by Supervisory Signals

Symptoms	Probable troubles	Corrections
Fuse alarm operates on power distributing fuse panel.	Short circuit or overload in power circuits.	Test circuit for trouble. Repair equipment and replace power fuse and alarm fuse.
	Defective alarm fuse.	If power fuse was not blown, replace alarm fuse.
Motor-generator control panel fuse alarm operates.	Open charging fuse or fuses.	Clear trouble in circuit, if any. Replace fuse and associated alarm fuse.
	Defective alarm fuse or fuses.	Replace alarm fuse.
	Open reverse-current relay fuse.	Test relay circuit and replace fuse.
Main battery fuse alarm operates.	Open main fuse.	Clear trouble in circuit, if any. Replace main fuse and associated alarm fuse.
	Defective alarm fuse.	Replace fuse.
Voltage alarm operates because of low voltage.	Main battery discharge or failure.	Check battery cells. Adjust motor-generator controls to charge battery.
	Motor-generator voltage too low.	Adjust generator voltage controls.
	Motor-generator paralleling panel fails to start No. 2 machine.	Check control circuits and motor generator.
	End-cell control switch fails to switch end-cells into main battery circuit.	Clean and repair end-cell control switch.
	Open LV relay coil or resistor, or contact springs out of adjustment.	Replace relay coil or relay. Adjust contact springs.
Voltage alarm operates because of high voltage.	End-cell control switch fails to switch end-cells out of main battery circuit.	Clean and repair end-cell control switch.
	Generator voltage too high.	Adjust generator control. Check control circuit and relays.
	Motor-generator control panel fails to cut No. 2 machine out of circuit when power load diminishes.	
Ringing current supervisory alarm operates steadily.	No. 2 ringing machine fails to start automatically when No. 1 machine shuts down.	Clean contacts on transfer relays. Test transfer relays. Test automatic starting switch. Clean ringing machine commutator. Replace commutator brushes.
	Generator hold-up relay (GEN HU) fails to operate.	Replace relay coil or relay.
Supervisory fuse alarm operates.	Open fuse or fuses in ringing, tone, or signal circuits.	Remove open fuse. Check circuit and clear trouble. Replace fuse.

73.248.1

Table 12-1.—Troubles Indicated by Supervisory Signals—continued

Symptoms	Probable troubles	Corrections
Group fuse alarm operates.	Open fuse or fuses on shelf fuse panel.	Remove open fuse. Check circuit and clear trouble. Replace fuse.
Release alarm operates.	Linefinder, connector, or selector failed to restore to normal position when released.	Restore switch manually. Busy out the defective switch. Repair, test, and place in service.
CDF (central distribution frame) lamps operate.	Operated heat coil or coils.	Test and clear line. Replace heat coils.
Permanent signal (PERM) on connector shelf.	Called party fails to disconnect.	Locate affected switch. Challenge on the line. Test line and use howler. Open line by removing heat coils. Make out trouble report.
	Calling party fails to disconnect.	Same as above.
	Short circuit or ground appears on line after connector has seized it.	Test as above. Open line by removing heat coils. Fill out trouble report.
Step signal (ST SIG) lamp glows on linefinder shelf and alarm buzzer operates.	Linefinder fails to step from normal position and hunt for calling line.	Locate faulty switch. Operate busying switch to remove faulty switch from circuit. Repair switch, test, and replace in service.
	Defective relay A-3 in group relays.	Clean and adjust contacts.
Supervisory signal lamp (SUPY) glows on selector shelf.	Calling party fails to dial or hang up after selector switch has been seized.	Challenge seized line. Test line and use howler. Fill out trouble report. Dispatch repairman to telephone set in question.

73.248.2

Table 12-2.—Troubles Indicated by Service Complaints

Symptoms	Probable troubles	Corrections
Noisy, intermittent, or poor transmission.	Wiper tips worn too thin.	Replace wipers.
	Insufficient tension on wiper tips.	Adjust wiper spring tension.
	Broken conductors in wiper cords.	Replace cords.
	Dirty switch bank contacts.	Clean switch bank contacts.
	Dirty relay contacts or insufficient contact spring tension	Clean relay contacts. Adjust contact spring tension, if required.

73.249.1

Table 12-2.—Troubles Indicated by Service Complaints—continued 73.249.2

Symptoms	Probable troubles	Corrections
Cannot make outgoing calls.	All trunks busy.	Instruct user to place call later.
	Linefinder or connector permanents, or off-normals.	Clear troubles and restore blocked switches.
	Defective telephone line equipment.	Repair defective line equipment.
	Defective line relay coil.	Replace relay coil.
Calling party does not receive dial tone.	Line relay contacts not making.	Clean relay contacts. Adjust contact spring tension, if required.
	Open resistor in linefinder start circuit.	Replace resistor.
	Fault in group relay circuit.	Check group relays.
	Rotary cam springs on first selector not making contact.	Clean and adjust cam spring contacts.
	Selector relay contacts not completing dial tone circuit.	Inspect for dirty or pitted contacts. Clean and adjust.
	All linefinders in group busy.	Advise telephone user to restore handset and to place call again.
Calling party does not receive busy tone.	Connector relay contacts not completing busy tone circuit.	Inspect for dirty or pitted contacts. Clean and adjust.
	Open capacitor in busy tone circuit.	Replace capacitor.
Calling party receives busy tone before completion of dialing.	All trunks are busy.	Check trunks for possible trouble. Advise telephone user to place call at less busy time.
Calling party does not receive ring-back tone.	Connector relay contacts not completing ring-back tone circuit.	Inspect for dirty or pitted contacts. Clean and adjust.
	Open capacitor in ring-back tone circuit.	Replace capacitor.
Bell does not ring.	Open-circuited or short-circuited line crossed with battery.	Test the line from the CDF.
	Open-circuited ringer.	Send repairman to the telephone set.
	Ringing current not being supplied to the line.	Check operation of the ringing group relays. Check each connector ringing relay in group. Clean and adjust relay contacts, if required.
Called party does not answer.	Same as above.	Same as above.
Calling party cannot hear called party.	Connector relay contacts not completing transmission circuit.	Make routine test of connectors. Inspect, clean, and adjust relay contacts.
	Reverse-battery relay does not supply battery to called party.	Inspect, clean, and adjust contacts.
	Open capacitor or capacitors	Replace the capacitors.

Table 12-2.—Troubles Indicated by Service Complaints—continued

Symptoms	Probable troubles	Corrections
	in connector transmission circuit.	
Called party cannot hear calling party.	Relay contacts faulty in preceding switches.	Test selectors, line finders, and line relays.
	Relay contacts on connector preceding switches not completing transmission circuit.	Make routine test of connectors. Inspect for dirty or pitted relay contacts. Clean and adjust.
	Reverse-battery relay does not supply battery to calling party.	Check, clean, and adjust contacts.
	Open capacitor or capacitors in transmission circuit.	Replace the capacitors.
	Relay contacts faulty in preceding switches.	Test selectors, linefinders, and line relays.

73.249.3

When you dial, you tell the control equipment the number you want. The control equipment then finds the proper path through the switching network and closes the necessary switches to complete that path.

MAJOR COMPONENTS

Major components of a crossbar office, organized according to function, are: a marker, an originating register, a number group frame, and a sender.

The MARKER is the brain of a crossbar. It marks points in the switching network through which calls must go and selects and establishes paths between these points. This operation is performed at the rate of about one-half second per connection.

An ORIGINATING REGISTER gives you a dial tone and remembers the number you dial—using relays and switches. Incoming registers perform the same function for calls from other central offices.

The NUMBER GROUP FRAME is a mechanical telephone directory which knows the number of every telephone in the central office. It knows to which terminals on which line link frame each telephone is connected and is prepared to give out this information anytime it is asked for by the marker. The SENDER transmits numbers, in special codes, that other offices are set up to receive. Different types of senders are provided to transmit signals to the different types of central office, such as step-by-step, crossbar, and manual offices.

SWITCHING NETWORK

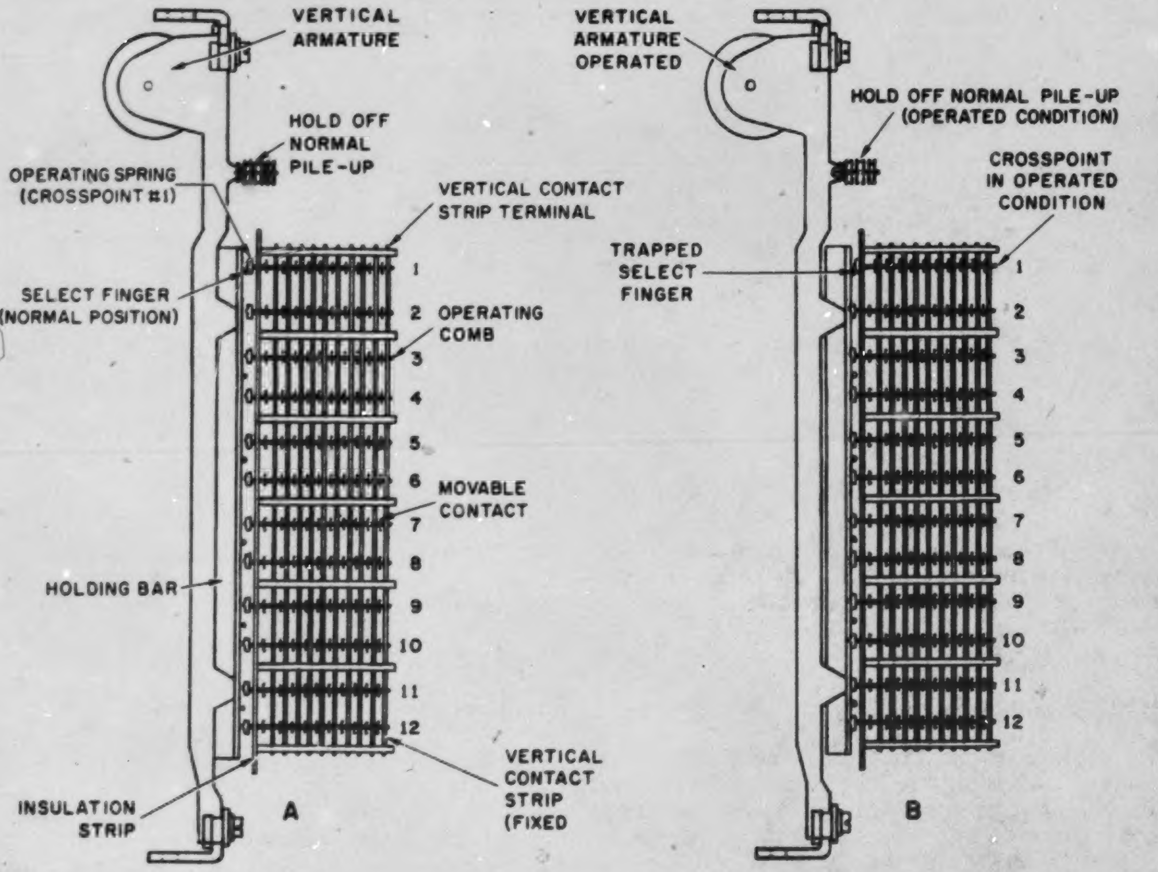
Two important units of the switching network are the line link frame and the trunk link frame.

The LINE LINK FRAME is a unit consisting principally of crossbar switches, to which telephones are connected. A line link frame is the first link in the call you make; it is also the last link, since any telephone you call is connected to a line link frame.

The TRUNK LINK FRAME is a unit to which trunks in the central office are connected. A trunk is simply a telephone line or circuit leading from one place to another. Such a line, which begins and ends in the same central office, is called an intra-office trunk. Lines on circuits which lead to or from other central offices are called outgoing or incoming trunks.

CROSSBAR SWITCH

The crossbar switch, which is the key unit of a crossbar switching network, differs from the step-by-step switch as radically as the two systems differ from each other. A crossbar switch is a rectangular device with horizontal and vertical bars crossing each other


VERTICAL ARMATURE
HOLD OFF NORMAL PILE-UP
OPERATING SPRING (CROSSPOINT #1)
VERTICAL CONTACT STRIP TERMINAL
SELECT FINGER (NORMAL POSITION)
OPERATING COMB
MOVABLE CONTACT
HOLDING BAR
INSULATION STRIP
VERTICAL CONTACT STRIP (FIXED
A
1
2
3
4
5
6
7
8
9
10
11
12
VERTICAL ARMATURE OPERATED
HOLD OFF NORMAL PILE-UP (OPERATED CONDITION)
CROSSPOINT IN OPERATED CONDITION
TRAPPED SELECT FINGER
B

73,341

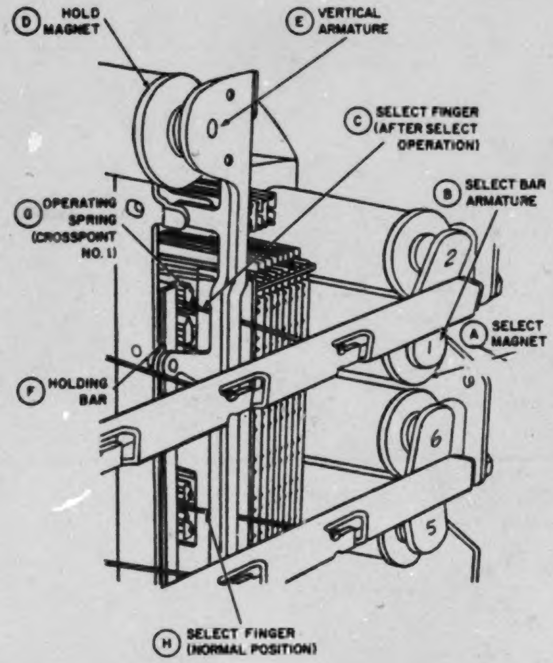
Figure 12-40.—Vertical unit after select operation; vertical unit after hold operation.

in a latticework fashion. These bars are mounted on a frame so that they can move (pivot or tilt) with the movements controlled by electromagnets. (See figs. 12-40 and 12-41.)

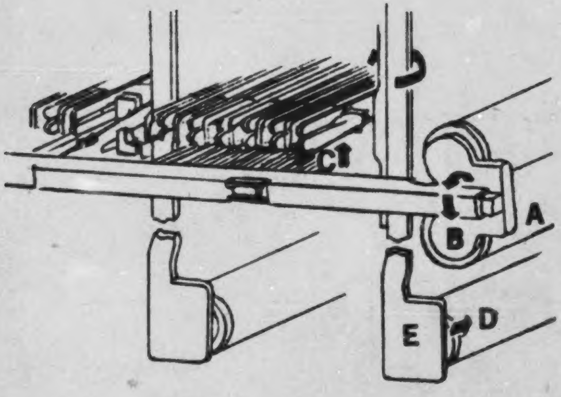
The principal components of the switches are relay type sets of contacts mounted one above the other behind the vertical bars. These sets of contacts are called crosspoints. To close a set of crosspoints and thereby complete a connection through the switch, first a horizontal bar moves and then a vertical bar (fig. 12-42). The switch design makes it possible to produce multiple connections. When connections are made, electrical paths are established as indicated in (figure 12-43.) Only three completed paths are shown, but as many could be made simultaneously as there are horizontal paths—10 in this case. The availability of so many connections is an important asset to the central-office switching networks.

TRACING A CALL

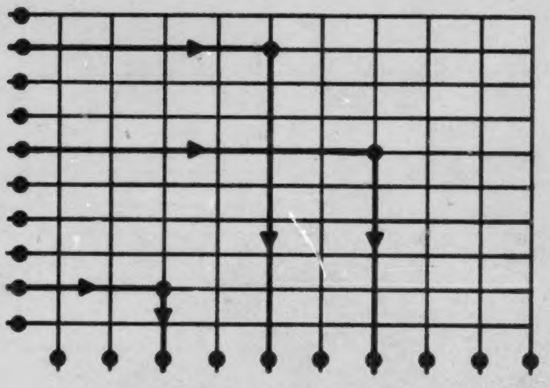
The block diagrams in figures 12-44 through 12-48 show how the different units in a crossbar


D HOLD MAGNET
E VERTICAL ARMATURE
C SELECT FINGER (AFTER SELECT OPERATION)
B SELECT BAR ARMATURE
G OPERATING SPRING (CROSSPOINT NO. 1)
2
1
A SELECT MAGNET
F HOLDING BAR
6
5
H SELECT FINGER (NORMAL POSITION)

73.342
Figure 12-41.—Sectional view of crossbar switch.



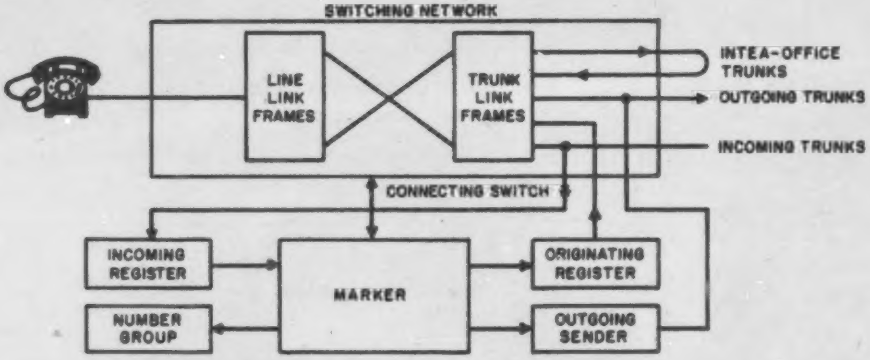
73.343
Figure 12-42.—Perspective view of part of a crossbar switch.



73.344
Figure 12-43.—Electrical paths established when connections are made in a crossbar switch.

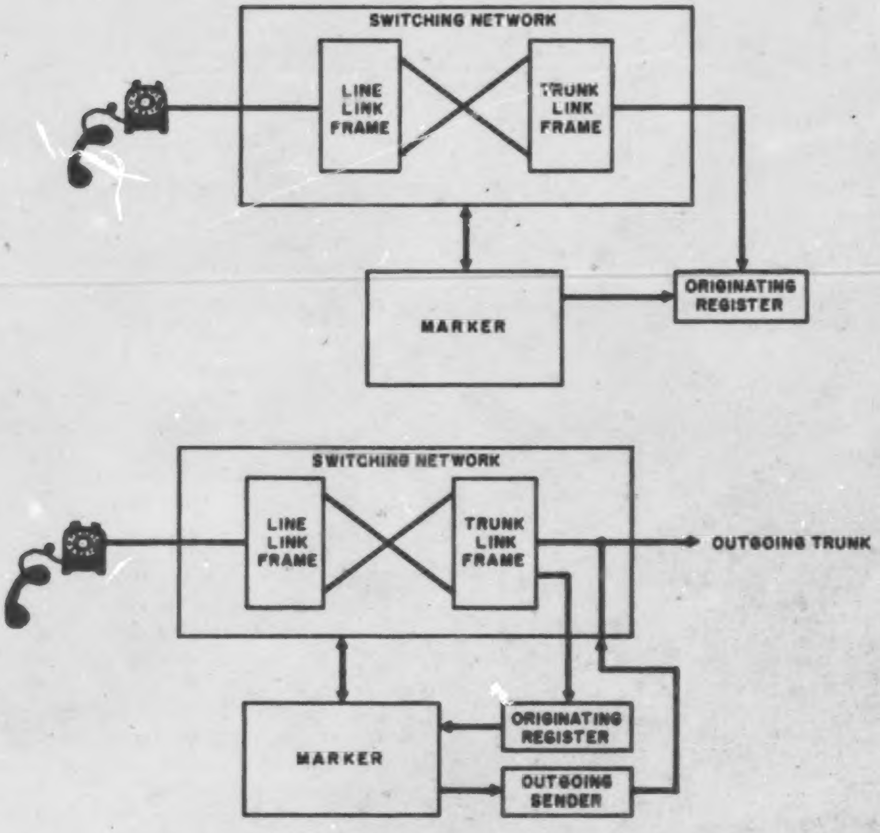
office are inter-connected (through crossbar switches) for an intra-office call. When you pick up your handset you are connected to your crossbar switch in a line link frame. (See fig. 12-44.) A marker is signaled and connects you to an originating register. The marker now disconnects itself to handle other calls. You hear the dial tone and dial the number you want which is recorded by the relays of the originating register.

The originating register now connects to an idle marker and transmits the number you want to the marker. (See fig. 12-45.) The first three digits of the number (known as the office code) tell the marker the name of the office called. Assume that the called number is in another central office. The marker, therefore, disconnects your line from the originating register, connects the proper sender to the proper outgoing trunk, and connects your line to the trunk through the line link and trunk link frames. The sender transmits the number you want to the other central office. In this second central office (figure 12-46), an incoming register records the number from the distant sender after which it connects to a marker. The marker receives the number from the register. The marker must now locate the called number in its office. To do this it checks the number group frames (fig. 12-47). This electrical telephone directory tells the marker the location of the number, the right line link frame, the crossbar switch, and so on. The number group frame and incoming register are dismissed by the marker, which now connects the incoming


SWITCHING NETWORK
LINE LINK FRAMES
TRUNK LINK FRAMES
INTEA-OFFICE TRUNKS
OUTGOING TRUNKS
INCOMING TRUNKS
CONNECTING SWITCH
INCOMING REGISTER
MARKER
ORIGINATING REGISTER
NUMBER GROUP
OUTGOING SENDER

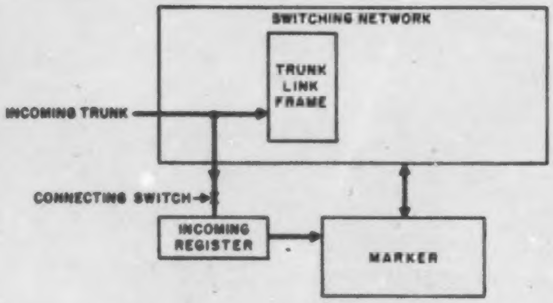
73.345

Figure 12-44.—Switching network.

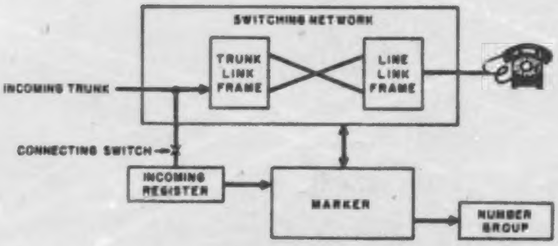

SWITCHING NETWORK
LINE LINK FRAME
TRUNK LINK FRAME
MARKER
ORIGINATING REGISTER
SWITCHING NETWORK
LINE LINK FRAME
TRUNK LINK FRAME
OUTGOING TRUNK
ORIGINATING REGISTER
MARKER
OUTGOING SENDER

73.346

Figure 12-45.—Block diagram showing how different units in a crossbar office are interconnected for an intra-office call.


SWITCHING NETWORK
TRUNK LINK FRAME
INCOMING TRUNK
CONNECTING SWITCH
INCOMING REGISTER
MARKER

73.347
Figure 12-46.—Path of call in second central office.


SWITCHING NETWORK
TRUNK LINK FRAME
LINE LINK FRAME
INCOMING TRUNK
CONNECTING SWITCH
INCOMING REGISTER
MARKER
NUMBER GROUP

73.348
Figure 12-47.—Marker connects the incoming trunk to the called number through a trunk link frame and line link frame.

trunk to the called number through a trunk link frame and line link frame. Since the connection is now complete, the marker disconnects itself and goes on about other business. The incoming trunk rings the called line. The call is complete when the called party lifts the receiver (fig. 12-48).

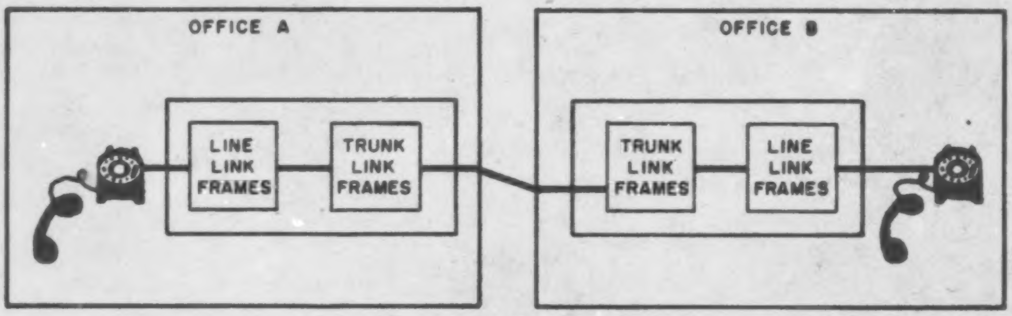
INTEROFFICE COMMUNICATIONS SYSTEMS

An interoffice communicating system is used to transmit orders and information among offices that are only a short distance apart. Frequently such offices are in the same building. Intercoms are not used at all advanced bases; if they are used, the job of installing and maintaining them usually falls to the CE.

The installation of an intercom system can be accomplished easily by following instructions that come with the set and using wiring diagrams.

An intercom system consists of one or more master stations, a junction box, one or more remote speaker units, and the wire necessary to make the connections. One type of intercom set is shown in figure 12-49. The master station has a capacity of 6 remote-microphone units; however, if one or more of the remote units are connected to the call-in circuit, the capacity of the system is only 5 remote stations.

The basic parts of the master station shown consist of a 3-tube chassis, a speaker-microphone, and a selector switch panel (fig. 12-50). The parts are installed in a wooden cabinet. A combination volume control and ON-OFF switch is mounted directly below the selector switch panel. The pilot light is illuminated at all times when the switch is on. A 3-position


OFFICE A
LINE LINK FRAMES
TRUNK LINK FRAMES
OFFICE B
TRUNK LINK FRAMES
LINE LINK FRAMES

73.349
Figure 12-48.—Completed connection through switching newtorks of two crossbar central offices.

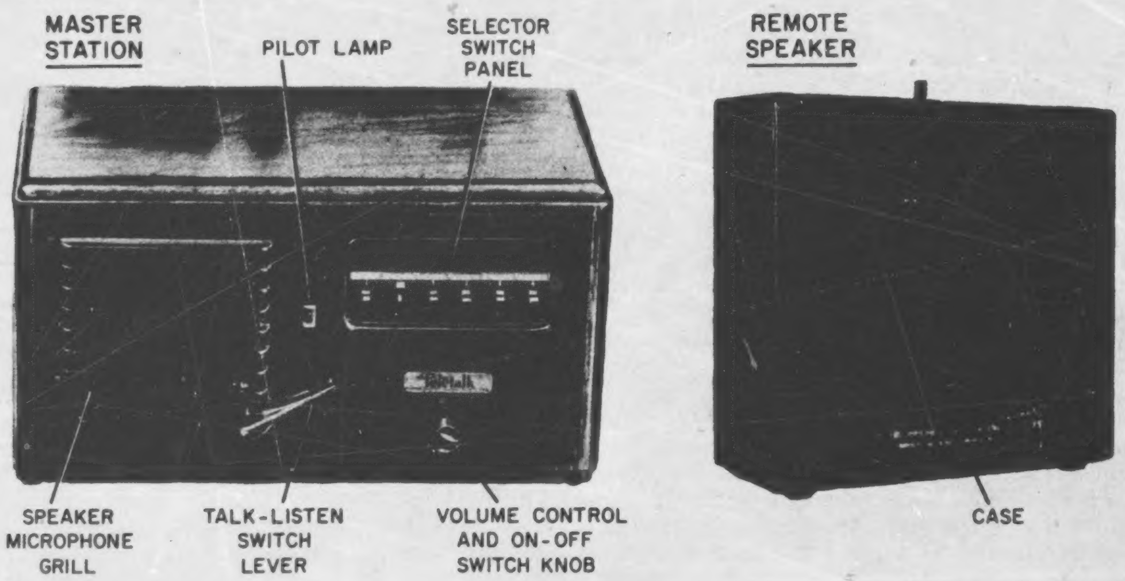

MASTER STATION
PILOT LAMP
SELECTOR SWITCH PANEL
REMOTE SPEAKER
SPEAKER MICROPHONE GRILL
TALK-LISTEN SWITCH LEVER
VOLUME CONTROL AND ON-OFF SWITCH KNOB
CASE

Figure 12-49.—Intercom set. 26.286

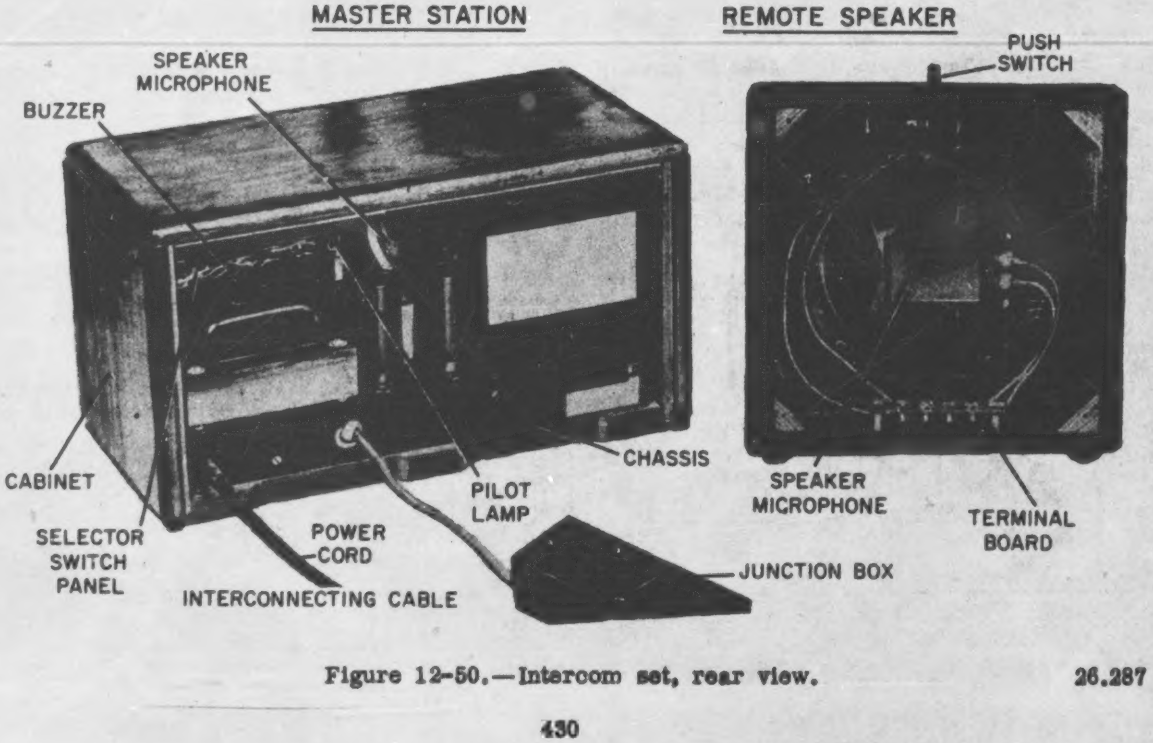

MASTER STATION
REMOTE SPEAKER
PUSH SWITCH
SPEAKER MICROPHONE
BUZZER
CHASSIS
CABINET
PILOT LAMP
SPEAKER MICROPHONE
TERMINAL BOARD
SELECTOR SWITCH PANEL
POWER CORD
INTERCONNECTING CABLE
JUNCTION BOX

Figure 12-50.—Intercom set, rear view. 26.287

switch at the center of the cabinet front controls talk-listen or idle position. The speaker-microphone is mounted inside the cabinet behind the grill on the front panel. A junction box, used for interconnection to remote stations, is attached to the chassis by flexible cable. An a-c power cord is attached to the chassis.

The remote unit consists of a speaker-microphone mounted in a wooden cabinet, a push switch for signaling the master station when intercommunications is desired, and a terminal board for interconnection to the master station.

The switch panel consists of the selector switches (6 for the model shown), a space above each switch for identifying the station, and an annunciator for each switch. (All intercoms are not equipped with annunciators.) The switches have three positions; OFF, ON, and a third position to operate annunciators on a remote annunciator's master station unit.

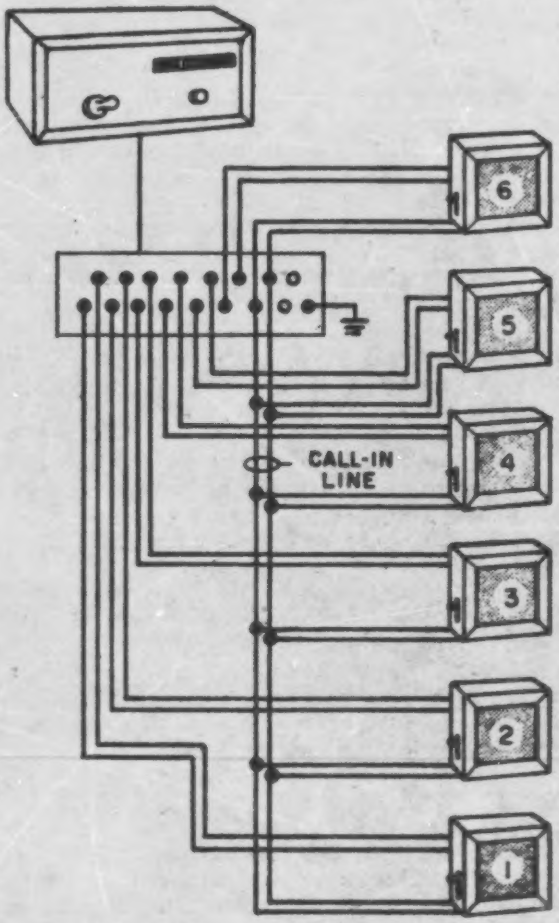
The annunciators are solenoid plungers mounted above each station selector switch. When the button atop a remote speaker-microphone is depressed, or when a switch on a remote master unit is pressed down, a buzzer at the master station sounds, and the annunciator above the switch for the calling station springs outward. The annunciator remains out until the operator pushes it in; it should be pushed back to its normal position at the same time that the selector key is raised to answer the call.

The talk-listen lever is a 3-position switch. The three positions are IDLE, LISTEN, and TALK. Under normal operating conditions, the lever should be left in the idle position. The idle position should be used to determine whether a station to be called is in communication with another station. Leaving the lever in the idle position, flip the selector switch of the station that is to be called. If no other station is conversing with this station, press the lever to the talking position and speak into the master station. If the system has only one master unit, you may press the lever into the talk position without going through the idle position, since remote speaker microphone units cannot communicate with one another.

INSTALLATION PROCEDURES

Any combination of master stations and speaker microphone units up to the capacity of the master station can be used. Where it is not necessary for remote stations to communicate among themselves, only one master station will be installed; this is the usual case. (Figure 12-51 shows a circuit with all remote speakers connected to call-in line.)

Install the master station within reach of a 110-125 volt, 50-60 hertz a-c power outlet. The master station and the speaker microphone units should be placed on the desks or in the working spaces of the personnel who will use them. If some of the units are installed outdoors, take the necessary precautions to protect them from adverse weather conditions.



26.131

Figure 12-51.—Six-station intercom system layout.

The size of the wires to be used in making connections between units is governed by the length of wire. For the voice lines, No. 22 to No. 19 twisted pair wire is used. The maximum wire resistance permissible will be stated in the operating instructions. For the model shown the maximum resistance is 50 ohms per pair. The amount of wire determines the wire size to be used. No. 22 wire gives a resistance of 32 ohms per 1000 feet, and No. 14 wire gives a resistance of 4 ohms per 1000 feet. The larger sizes of wire (lower number) should be used when long lengths are necessary to connect the units.

The wire resistance of the annunciator lines must be kept below 15 ohms per pair. Normally, No. 14 or No. 16 wire is used.

All connections to a master station unit are made on the junction box. Be sure that the interstation wires do not cross hot pipes. The wires should never be placed where they are in danger of being covered by water.

After the wiring is installed, check the resistance with an ohmmeter. Make certain that the maximum permissible resistance is not exceeded and that there are no opens, grounds, or shorts. (Note: Follow installation instructions that come with each new set.)

TROUBLESHOOTING

Many of the troubleshooting instructions that apply to switchboards apply equally to intercom systems. In general, troubleshooting techniques consist of five steps:

1. Look
2. Feel
3. Tighten
4. Clean
5. Adjust

The first step consists of looking for such items as unlit tubes, frayed or broken wires, broken component connections, and dirt.

The feel operation is necessary to check and determine if electrical components are overheated. Be certain that the power is disconnected before performing this operation.

The tightening, cleaning, and adjusting operations are self-explanatory.

Components in intercom sets are readily accessible and may be easily replaced if found to be faulty. When a defective component such as a burned-out resistor or transformer is located, remember that the cause of the condition may be in some other part of the circuit. If the cause is not located and corrected, the new part will be burned out in the same way as the one that was replaced.

When trouble develops in an intercom system which has been properly installed and has been operating properly, the fault will usually be in one of the units of the system rather than in the interstation wiring. If the fault is in the interstation wiring it can easily be traced because the units will usually operate properly on some branches of the system. Once a fault has been traced to some particular unit it can sometimes be located by sight or smell (burned-out resistors and shorted transformer) but most faults must be traced by checking voltages and resistances.

In troubleshooting ALWAYS REMEMBER:

1. Noise or hum may be mechanical noises picked up by the microphone and amplified at the master station; or it may be caused by office equipment, or other external causes.

2. The majority of master station trouble can be traced to faulty tubes. Replace the tube with a set of tubes known to be good before becoming involved in major troubleshooting procedures.

Before parts are unsoldered the position of the leads should be noted. If the part has several connections to it, each lead should be tagged. Care should be taken that other leads are not damaged by being pulled or pushed out of the way.

Remember the following facts when you are soldering connections:

1. A carelessly soldered connection may create a new fault.

2. A poorly soldered joint is a very difficult fault to locate.

3. Don't allow drops of solder to fall into the set as they may cause a short circuit.

These points should be remembered particularly when leads are being soldered on intercoms. This information however, applies to soldering of all communications equipment.

PUBLIC ADDRESS SYSTEMS

During the early stages of an invasion, portable types of public-address systems are in extensive use for making amplified-voice announcements in the landing area. Small types of PA systems are d-c battery powered and completely self-contained. For strong sound coverage required to overcome a high level of noise in the area, a large a-c portable PA system, powered by a gasoline engine-driven generator, is used.

At an established base a PA system may be used for the auditorium, for outdoor movies, and for camp-wide announcements. The system generally used is a portable set consisting of a 100-watt cabinet-type amplifier, a dynamic (movable coil) microphone with heavy-duty floor stand, two 25-ft lengths of shielded microphone cable, and one 25-ft length of heavy-duty power cable. The system requires a 100/125 volt, 50/60 hertz power source.

The horns used as loudspeakers can be controlled individually or in any combination. The speaker can address a single station, several stations, or all stations. A changeover switch is provided to allow signal input from either a microphone or a phonograph.

As with any electrical circuit, the wiring diagram provides the key for the proper wiring connections. Normally, No. 14 size wire should be used for wiring connections. Horn loudspeakers may be mounted on buildings, poles, speaker stands, or even in trees. In selecting a permanent location for a loudspeaker, you should test for uniform loudness, minimum echo, and the possibility of an acoustical dead spot.

When installing a PA system, make sure you follow the manufacturer's instructions carefully.

COMMUNICATIONS MAINTENANCE AND REPAIR

The best possible equipment develops occasional faults in service. Also, the addition of new circuits, the placing of cross connections, the installation of local switchboards, and similar changes and rearrangements may be required. It follows that maintenance means more than just cleaning and lubricating. Besides what has been suggested, maintenance includes preventive maintenance—that is, a set routine of periodical tests, checks, and inspections, designed to head off trouble before it develops to the extent that it causes damage.

BATTERY MAINTENANCE

Inspect containers regularly for dirt, dust, or cracks. Clean them with a dry cloth, never with a damp or wet cloth.

Examine the terminals and the straps between the cells for looseness or corrosion. If terminals need tightening, do not use excessive force because it may damage the connections. Remove corrosion with sandpaper or crocus cloth.

Check the electrolyte for level and for specific gravity. The level should be at the upper red line on the jar. To check specific gravity you use a pilot cell. Use a new cell after every 50 readings.

For telephone storage batteries the voltage should be at least 46 but not more than 52 volts if the batteries are charged during use. Violent gassing and temperature rise in the electrolyte indicate that the charging current is too high.

Guard against fire hazards at or in the vicinity of batteries. Loose connections can be very dangerous because of the possibility of sparking. AT ALL TIMES keep open flame, lit tobacco, or any other type of fire, however small, away from batteries.

CIRCUIT TESTING

All circuits should be tested at regular intervals. When you know a fault exists, the wiring diagram is an invaluable aid in helping you to pinpoint the location. If you cannot find a broken wire, faulty connection, or other fault available to casual inspection, you will have to locate the trouble by continuity, voltage, and resistance measurements. Start at a point where the circuit is known to be good (up to that point), and isolate parts beyond, step-by-step, until you have located the fault.

WIRING MAINTENANCE

Most of the maintenance on wiring will be corrective rather than preventive—that is, it will consist of the location and correction of faults which have become evident. However, you will inspect terminal boxes for broken lugs and defective faceplates; and you will check drop wires for adequate support, connections, and insulation. Most of your maintenance on wiring, however, will consist of locating and correcting opens, grounds, and shorts.

If the signal lamp on a switchboard lights continuously, a ground is indicated. Check the ring line (or tracer wire) first. Place the receiver of your test telephone in series with the tracer line at the nearest terminal box. If you hear a sharp click, move to apoint nearer the defective telephone. When you hear no click, the ground is between the point where you then are and the last point where you heard a click.

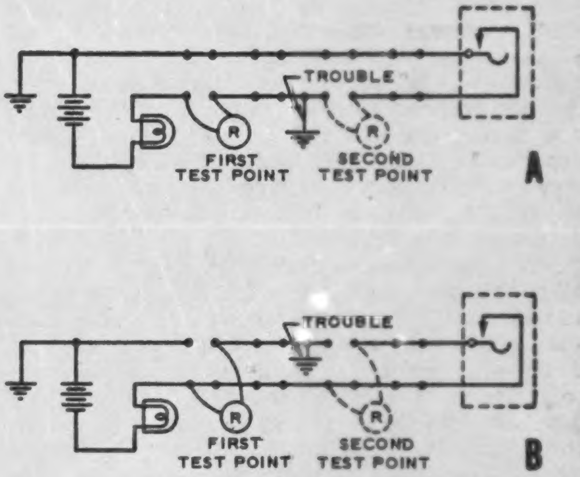
If the ground is in the plain conductor or tip line, there will be a noise on the circuit, caused by ground returns of other currents. Disconnect the tip line from its terminal at the pole, and then attach your test receiver leads to the ring line and to the part of the tip line that leads to the defective telephone. A click indicates that the ground is between you and the subset. Keep moving toward the subset until you fail to get a click. This indicates that the ground is between the point where you are now located and the last point where you received a click.

The diagrams in figure 12-52 illustrate the method of testing a ring line and a tip line for ground.

To locate an open circuit in one of the pairs of wires, start at the terminal box which is closest to the central office, and which has terminals tapped to the pair of wires to be tested. Connect the leads of your test telephone across the proper terminals. One lead should be clamped on, the other just tamped against the terminal. If you fail to receive a sharp click, one line in the overhead cable is dead, and will require splicing at the open. You may hear a very faint click, but this will be caused probably by a difference in ground potentials and not by battery voltage.

If you hear a sharp, definite click, you can be assured that battery voltage is present up to that point—meaning that there is no open in the line up to that point. The next point of testing will have to be the terminal box to which the drop wire is connected. A sharp click at this point indicates that the open is in the drop wire or the inside wiring.

The dividing point between drop wire and inside wire is the protector, so make that the next testing point. If no click is received when you place the test leads across the protector, the open is probably in the drop wire. Perhaps an inspection will indicate the break, and you can splice the wire. Otherwise you may have to replace the entire drop wire.



73.191

Figure 12-52.—Testing for ground. (A) Ring line; (B) Tip line.

To determine if the ground line at the protector has an open, use your test telephone leads where the pair of wires comes into the protector, by attaching one lead to the ring line, and tapping the tip line with the other lead. If you receive a click, tap the ground line (instead of the tip line) with the second lead. A click indicates that the circuit is good to ground. Absence of the click indicates an open.

To locate a short, go to the first check point and place your test receiver in series with the tip line. A click indicates that you are between the short and the central office, so keep working along the drop line until you fail to receive a click. At that point, you are beyond the short, so you know it lies between the last two points that you tested.

SUBSET MAINTENANCE

The first step in checking a subset is to identify the cause of the trouble. It may be only a loose connection, or the presence of some foreign material or iron filings around the ringer magnet.

You should know the number and location of the subset, the cable pair number, the location and number of the cable terminals, and the location and number of the cross-connecting box, if any. Examination of any previous trouble reports is helpful, because previous troubles may suggest the nature of present troubles.

Subset troubles may usually be broadly divided into those that lie between the central office and the subset and those that lie in the subset itself. For those between central office and subset a good point of beginning is the main distributing frame. This is the dividing point between outside plant and inside plant, and also the point of location of the central office protective devices.

Check the protector (where drop wire connects with inside wire); look for moisture; check for broken, defective, or loose fuses; replace badly pitted carbon blocks; check the ground wire.

At the subset, examine the transmitter for cracks or breaks in the mouthpiece; for missing rim screws or loose contact springs; and for dirt or moisture. Look inside the receiver for dirt, corrosion, moisture, or cracks. Examine the mounting of the ringer, and look for dents or cracks in the coils. Observe the contact and lever action of the hook switches, and look for rusty, bent, or pitted springs. Check to see that stay cords and hooks are secure.

The main thing is to put the line back into service as soon as possible, so for considerable repair, replace the subset and send the defective one back to the shop.

SWITCHBOARD MAINTENANCE

Inspection, tightening, cleaning, and adjusting are the basic operations in switchboard maintenance. Periodic inspections are of the utmost importance, because a minor defect may not interfere at once with the performance of the equipment, but may lead in time to a major breakdown. Keep all food and beverages away from the switchboard.

Every day the switchboard exterior should be wiped off with a soft, dry cloth. The batteries, headset, chestset, and exterior of the distribution frame should be inspected. Chipped paint, mildew, and corrosion must be removed, and the storage batteries must be checked for electrolyte level. Do not forget to inspect the wiring on the rear of the panel.

Weekly inspection should be given to cords, keys, shutters, fuses, protector blocks, heat coils, repeating coils, and ground rods.

Inspect the cords for dirt, dust, or fungus. Check the cord weights and pulleys for smooth operation. Wipe the cords with a clean, dry cloth.

Use long-nosed pliers to adjust the drop shutter latches. Then test to see if the shutters fall freely when a call is received, but remain in place when the switchboard is jarred.

Ascertain that fuses are of the proper capacity, and tighten the fuse mounting screws.

Remove dust, dirt, or other foreign matter from the protector blocks, and replace porcelain or carbon blocks that are chipped or broken. Use care in cleaning, because if you dislodge a block you can cause trouble on an incoming line.

Inspect heat coils for cleanliness, and replace any that show chipped or broken coils. Do not remove the covers of repeating coils, but examine the mountings for loose, damaged, or missing screws. Clean the coils with a dry, clean cloth.

Look for rust or corrosion on ground rods. Check to make sure that the wing bolt at the terminal connection is tight.

Plugs, relays, capacitors, terminals, binding posts, and cables should be given monthly inspection. Clean the switchboard plugs with cord plug polish, using a clean, dry cloth. Remove all residue of the polish after cleaning in order to maintain good electrical contact.

Inspect relays and capacitors for dirt and foreign matter, and clean with a dry cloth.

Inspect terminals and binding posts on the switchboard for cleanliness and tightness of connections. Check incoming line connections for good electrical contact. Tighten any loose terminals with a suitable screwdriver or wrench.

Clean the terminals and binding posts with a soft bristle brush.

Examine connecting cables for damaged or worn insulation. Check the fittings on the ends of the cables for tightness and good electrical connection. Tighten the connections on the cables as required.

INTERCOM SYSTEM MAINTENANCE

In general, the four basic steps in switchboard maintenance—inspect, tighten, clean, and adjust—apply to intercom system maintenance as well, with inspection being always of primary importance.

The components in an intercom set are all readily accessible, and for the most part they can easily be replaced when they are found to be faulty. However, you must have enough knowledge of the working principles of the system to be sure that the defective part is the cause of, and not a result of, trouble in the system.

For example, suppose you find a burned-out transformer or resistor. You replace it, and the replacement burns out. Actually, the burned-out part was not the cause of the trouble, but a result of it.

PUBLIC ADDRESS SYSTEM MAINTENANCE

Trouble in a PA system is often caused by nothing more obscure or complex than a loose cable connection or a break in the cable shield. Check for simple faults of this type before you begin a lengthy system of tests.

In soldering connections, make certain that both metals are absolutely clean, and that the completed soldering job is firm and durable. Faulty soldering in a PA system can cause defects which are very difficult to identify and locate. Too much solder can cause shorts in microphone connectors that may not be visible to the eye.

The identification and location of serious troubles in the system may require the use of signal tracing equipment, such as an audio-signal generator, an output meter, or an oscilloscope. In testing the electric circuit, the most important point to remember is that the trouble should be pinpointed as to location. A careful study of the circuit diagram is essential.

TOOLS AND EQUIPMENT

Tools and equipment required for maintenance and repair are included as part of a field telephone set component. For subsets taken out and sent to the shop for repair, the maintenance tool is the same test telephone which you use in locating shorts, opens, or grounds.

In general, you should have the following tools, equipment, and materials available when you begin any cleaning, adjustment, or repair process:

Test telephone
Clean, dry cloths and soft bristle brushes
A drycleaning solvent
Cord polish
Crocus cloth or No. 000 sandpaper
Screwdriver set
Long-nosed pliers
Wrench sets, both open and socket
Battery hydrometer

CHAPTER 13

TELEPHONE CABLE SPLICING

Telephone cable splicing is an important function of the CE's job. This chapter provides information that will aid you in splicing telephone cable safely, economically, and efficiently.

The knowledge you acquire in this chapter regarding cable terminology, types of cable, and the procedures for splicing a variety of cables will enable you to render vital services in the communication link.

Most lines, whether for telephone or for power distribution, require some splicing. The length of cable on a reel seldom equals exactly the length to be installed. Even after a system has been installed, there will always be a certain amount of splicing necessary, to take care of repairs on defective cable sections, or to add extra sections to the main cable.

Whenever splicing is required, remember that you are playing a vital role in keeping communication lines operating properly.

TELEPHONE CABLE CLASSIFICATION

There are four types of telephone cables: lead-covered, tape-armored, building and switchboard (silk and cotton), and plastic-covered (polyethylene) cable. For many years, lead-covered cable was used more than the other types. However, plastic-covered cable is now being used more than the lead-sheathed type for two reasons: plastic cable is cheaper to produce than lead, and it also has the advantage of being lighter in weight than the lead-sheathed type. You can expect to be working much of the time with plastic-covered cable, and in some cases you will be replacing existing lead-covered cable with plastic-covered cable. Two considerations will determine the selection of the type of cable to be used: the job it will perform and the kind of environment into which it will be placed.

There are four types of cable installations: aerial, direct-burial, underground and submarine. Aerial installation is aboveground, and most of your experience will be with this type. When cable is buried directly in the ground without conduit, you have a direct-burial installation. In an underground installation, the cable is installed underground in conduits. Sometimes cable must be installed in submarine areas; that is, under water or in swampy areas.

The following paragraphs tell about the different kinds of cable, how they are used, and how they are installed.

LEAD-COVERED CABLE

Lead-covered cable is insulated with paper. The insulation may be sprayed on as a pulp, or the paper may be wrapped spirally around the conductors. Double-wrapping of wires provides a highly dielectric (non-conducting) insulation, both because of the additional thickness of the paper and because of the additional air space. This higher insulation protects against insulation breakdown which might occur if a telephone line came into contact with a powerline. Lead-sheathed cable is used for installations underground in conduits.

TAPE-ARMORED CABLE

Tape-armored cable is a lead-covered cable fitted with a protective covering of paper, jute, and steel tape. This covering protects the cable against damage by rodents and against mechanical damage. It is used for direct burial (placed underground without conduit) and also for submarine installation; that is, in swampy land or water.

Tape-armored cable is quadded, colored-coded, and composite. In quadded cable, some or all of the conductors are arranged in quads, or groups of two pairs. A cable containing 26 or more pairs of conductors is color-coded according to groups, to simplify matching for splicing. Composite means that the cable contains conductors of two or more sizes.

BUILDING AND SWITCHBOARD CABLE

Building cable is made up of copper conductors covered with weatherproofed neoprene jacket insulation. It is used to make connection from telephone poles to buildings.

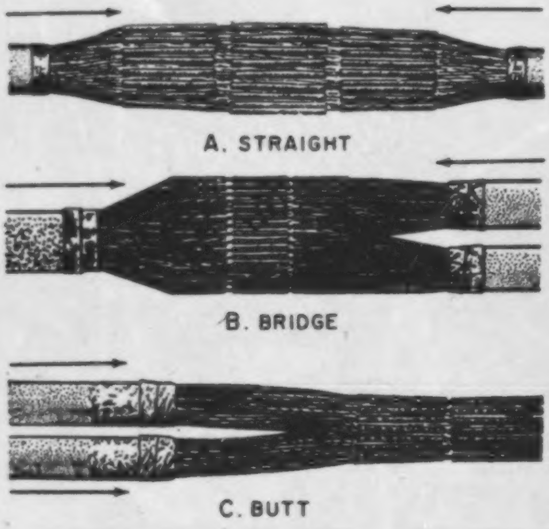
Switchboard cable is made up of copper, or tinned copper, conductors with a silk and cotton insulation; but it is also available with black enamel insulation. Pairs of conductors are usually bound together with a spiral layer of paper, a layer of lead tape, another layer of paper, and a fireproofed braid. The insulation is colored according to a standard color scheme, so that each pair of wires and each unpaired single wire can be identified. Switchboard cable is used to connect the switchboard apparatus to the main distribution frame. It may also be used for local wiring in the switchboard. On newer installations, the switchboard cables, or jumper wires, will probably be No. 22 copper conductors with a plastic insulating jacket. This wire ordinarily comes on 1000-foot spools and is used primarily for making connections on the main distribution frame.

PLASTIC-COVERED CABLE

Polyethylene or plastic-covered cable has solid copper conductors, each with polyethylene insulation. It is used in aerial installation; that is, suspended on poles, and for direct burial underground without conduit.

SPLICING TELEPHONE CABLE

The three most commonly used types of telephone cable splices are the straight splice, the bridge (sometimes called branch) splice, and the butt splice. These three types are illustrated in figure 13-1. In view A of figure 13-1 the cables come from opposite directions, the splice in each individual wire being covered by a small cotton sleeve. In view C, the wires enter the sleeves from the same direction. In view B, however, two cables coming from one direction have been spliced to a single cable coming from the opposite direction.



73.192
Figure 13-1.—Types of telephone cable splices.

Straight splicing is the simplest method of splicing, consisting as it does of joining two wires that approach the splice point from opposite directions. Most of the splicing that you do will be by the straight splicing method. Bridge splicing usually consists of splicing a branch into a main cable. Butt splicing is usually done to attain flexibility; a butt splice is often later changed to a straight or bridge splice.

SPLICING LEAD-SHEATHED CABLE

While most of the splices that you make in lead-sheathed cable will be straight splices, you will also on occasion make bridge and butt splices in this cable. The procedure below applies to all three types of splices. The steps of the procedure are as follows:

1. Mounting the sleeve.
2. Removing the sheath from each cable end.
3. Drying out the insulation by boiling out or by using a desiccant.
4. Identifying and selecting the correct individual wires from each cable.

5. Splicing the wires in a staggered pattern.

6. Placing and wiping the sleeve.

The following sections explain each of these steps in detail.

Mounting Sleeve

The size of the lead sleeve will depend on the size of the cable, the diameters and number of wires, and the type of splice. The splice on a pair of individual wires is covered with a small diameter cotton or plastic sleeve. The size of the cotton or plastic sleeve depends on the diameter of the spliced wires it covers. The whole splice—that is, the bundle of spliced individual wires—is covered with a larger diameter lead sleeve.

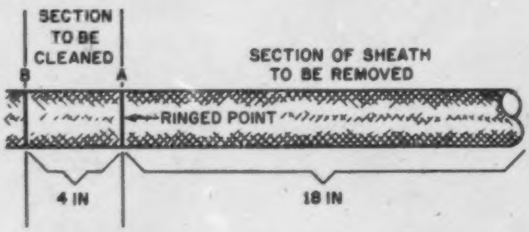
It is advisable to slide the lead sleeve onto one of the cables as soon as the ends have been arranged and prior to the preparing and removal of the lead sheath. Slip the sleeve up the cable far enough to have it out of your way as you perform the individual wire splicing operations. When all the wire splices have been completed, you can draw the sleeve down over the bundle.

Before you slide the lead sleeve on, inspect it for cleanliness and for sharp edges. If necessary, smooth up the ends with a lead file.

Removing the Sheath

Measure the length of the sheath to be removed, and ring the cable at the point where the cut is to be made. The diagram in figure 13-2 shows a distance of 18 inches, but this is only by way of illustration. In every case the length of the splice opening will depend on (1) the size of the cable (in terms of the number of pairs of wires), (2) the diameters of the conductors, and (3) the type of splice being made.

In ringing the cable be sure, as with power cable, that the cut or score does not penetrate completely through the sheath. A too-deep cut may damage the conductors, whereas a properly shallow cut bells the sheath, as desired, when the section to be removed is pulled off.



73.193

Figure 13-2.—Preparing cable for splicing.

Clean the sheath back from the ringed point (distance AB in fig. 13-2). On new cable use a file as a cleaner. On old cable a shave hook is better. If dull or dark streaks are left they will not tin properly when the joint is wiped later, and the joint will be defective.

Immediately upon cleaning this area, and before your hands have touched it, coat it with stearine, and wrap it with a double layer of boiled-out muslin. This is to protect the area while you are removing the adjacent length of sheath for the splice opening.

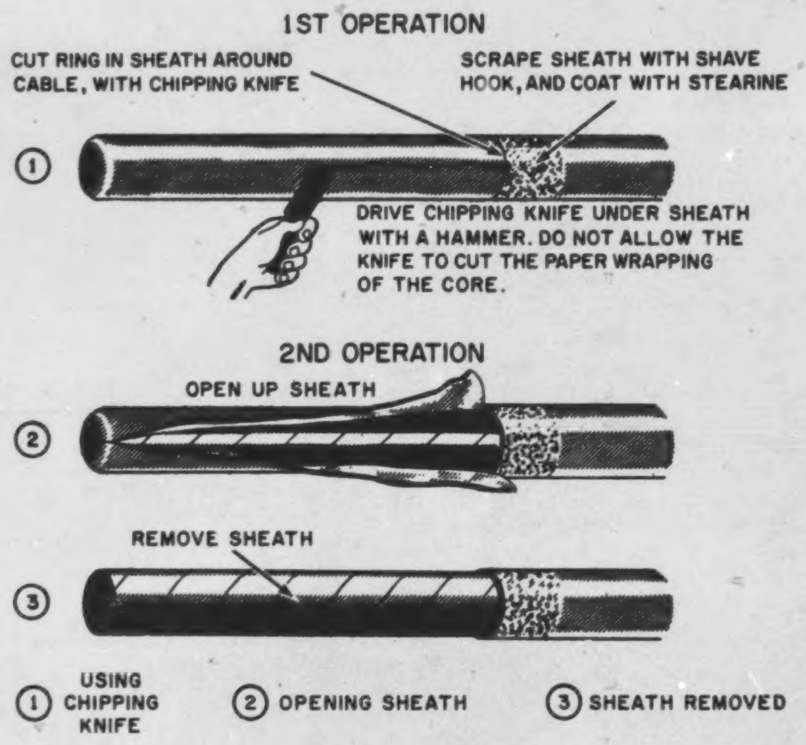
You split the sheath with a splitting knife (also called a chipping knife) as described for power-cable splicing in chapter 11. You must avoid cutting through the paper wrapping of the cable core, so be careful in driving the knife under the edge of the split to loosen the sheath.

Grasp the cable at the section where you wrapped it in the protecting layer of muslin, and gradually work off the split portion of the sheath. It should break off at the ringed point. Figure 13-3 shows the main steps in removing the sheath.

When the sheath has been broken off, inspect the broken-off edges on the cable ends to ensure that they are smooth. Any sharp edges or burrs could cause damage to the conductor insulation during splicing. The best way to guard against this is to butt the sheath edges with boiled sleeving muslin, or cotton tape, as shown in figure 13-4.

Boiling Out Insulation

"Boiling out" is a term used to refer to a procedure for removing any moisture which may be present in the insulation. Besides removing moisture and preventing the same from reentering the break, boiling out makes it easier for you to remove the paper insulation from individual wires when you are ready to splice them.


1ST OPERATION
CUT RING IN SHEATH AROUND CABLE, WITH CHIPPING KNIFE
SCRAPE SHEATH WITH SHAVE HOOK, AND COAT WITH STEARINE
①
DRIVE CHIPPING KNIFE UNDER SHEATH WITH A HAMMER. DO NOT ALLOW THE KNIFE TO CUT THE PAPER WRAPPING OF THE CORE.
2ND OPERATION
OPEN UP SHEATH
②
REMOVE SHEATH
③
① USING CHIPPING KNIFE
② OPENING SHEATH
③ SHEATH REMOVED

73.194

Figure 13-3.—Steps in removing sheath.

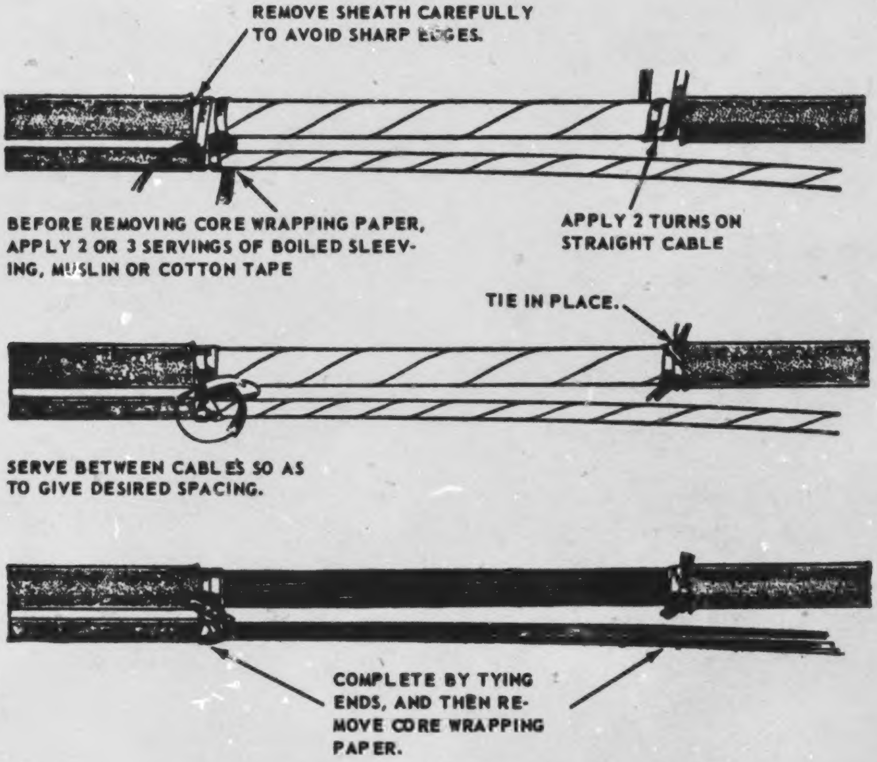
Boiling out consists of pouring hot paraffin over the sheath, starting about 6 inches back from the exposed wires, and gradually working the stream of paraffin onto the paper insulation and out to the ends of the wires. The temperature of the paraffin should not exceed 375° F—temperature higher than 390° F will damage the paper insulation. If you do not have a thermometer capable of registering such high temperature, you can apply a practical test to the paraffin when it is heating. Watch the dry ring that forms and gradually creeps up on the outside of the pot. This ring will begin to form when the paraffin is at about 360° F. When the ring is about 2 inches wide, the paraffin is at the correct working temperature.

The paraffin, as it cools and hardens, forms a seal which excludes the entrance of moisture. When you are splicing large cable, it is advisable to repeat boiling out as soon as you have spliced 200 pairs of wires. The reason is that by the time you have spliced 200 pairs of wires the insulation will have begin to absorb moisture from your hands and from the atmosphere. Another boiling out will remove this moisture and reseal the insulation.

If the splice is left incomplete overnight, or if you are working in a very damp atmosphere, you may have to go through the boiling-out process several times. Discoloration of the insulation or a bluish-green discoloration of the conductors are sure signs that excessive moisture is present. If discoloration is present, boil out again.

Drying By Desiccant

The paraffin boiling-out method of drying has several disadvantages. These include fire hazard, objectionable fumes, possible burns to personnel, and splashes of hot wax on floors or walls. The


REMOVE SHEATH CAREFULLY TO AVOID SHARP EDGES.
BEFORE REMOVING CORE WRAPPING PAPER, APPLY 2 OR 3 SERVINGS OF BOILED SLEEVING, MUSLIN OR COTTON TAPE
APPLY 2 TURNS ON STRAIGHT CABLE
TIE IN PLACE.
SERVE BETWEEN CABLES SO AS TO GIVE DESIRED SPACING.
COMPLETE BY TYING ENDS, AND THEN REMOVE CORE WRAPPING PAPER.

73.195

Figure 13-4.—Butting the sheath.

method of drying by the use of a desiccant (drying agent) is therefore often used instead. The usual desiccants employed are anhydrous calcium sulfate and silica gel. A desiccant absorbs moisture whereas hot paraffin drives it out.

A desiccant is used after the splicing and sleeving are completed. The splice bundle is enclosed in a muslin envelope long enough to overlap at both ends of the splice. Open one end of this envelope and let the desiccant trickle in all over the conductors. Spread the wires apart with your fingers to allow good penetration.

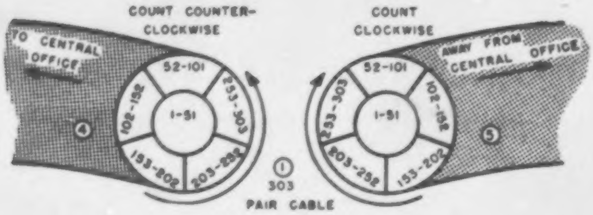
Conductor Identification

Conductor identification is predicated upon the establishment of a pair count. This operation is indispensable to the proper testing and splicing of telephone cable. Three considerations are involved in the count: the relative position of cable and central office, geometric pattern, and tracer pairs.

POSITION OF CABLE AND CENTRAL OFFICE.—The first consideration in the establishment of the count is the relative position of the central office and the cable end to be spliced. If the exposed end faces away from the central office, the count is made in a counterclockwise direction. If the exposed end faces toward the central office, the count is made in a clockwise direction (fig. 13-5).

GEOMETRIC PATTERN.—Cable may contain various quantities and combinations of geometric patterns (fig. 13-6). The count begins at the center of the core and proceeds to the sheath in a clockwise or counterclockwise direction.

As an aid in establishing or determining identification of pairs, the cable cores are color

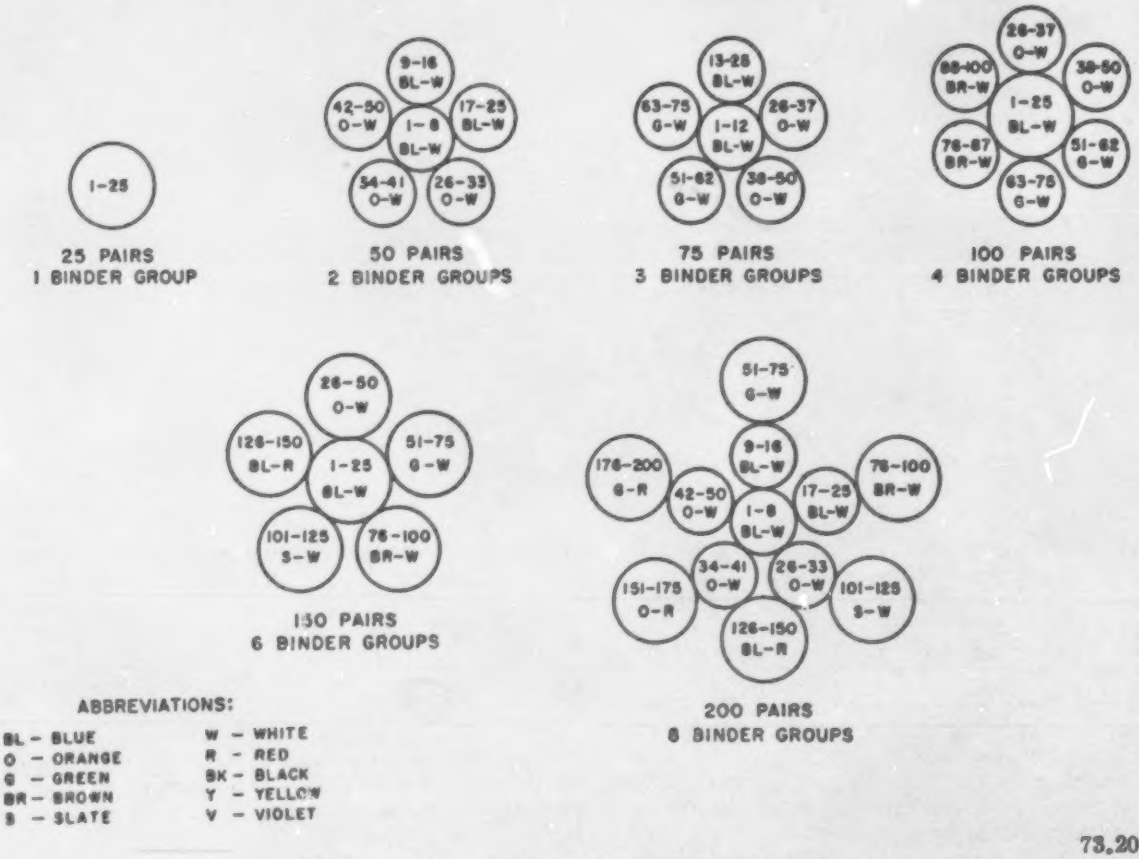

COUNT COUNTER-CLOCKWISE
COUNT CLOCKWISE
TO CENTRAL OFFICE
AWAY FROM CENTRAL OFFICE
52-101
102-152
1-51
253-303
153-202
203-252
④
⑤
①
303 PAIR CABLE

73.201.1
Figure 13-5.—Cable conductor groups, 303 pair cable.

coded by layers or groups bound separately by colored, spirally wrapped, soft textile binders or markers.

A group of 25 pairs is considered as the most suitable size for a uniform group, and all standard size cables, except those smaller than 25 pairs, can be divided by this number. The pairs within the 25-pair groups are identified by a simple code that uses 10 colors, 5 for tip and 5 for ring, with no duplication. The 25-pair groups (table 13-1) are bound with bicolor binders which follow the 5 + 5 color code used for pairs.

TRACER PAIRS.—The core of non-polyethylene insulated cable contains certain distinctively colored conductors known as tracers. A tracer pair is used by the splicer to establish a talking pair to his helper at the distant end of a length of cable being spliced at a terminal or at the main distribution frame in a central office. Terminated tracers are connected to the highest number terminal for that cable or group. A 101-pair terminal would have the tracer


1-25
25 PAIRS
1 BINDER GROUP
9-16 BL-W
42-50 O-W
1-8 BL-W
17-25 BL-W
34-41 O-W
26-33 O-W
50 PAIRS
2 BINDER GROUPS
13-25 BL-W
63-75 G-W
1-12 BL-W
26-37 O-W
51-62 G-W
38-50 O-W
75 PAIRS
3 BINDER GROUPS
26-37 O-W
88-100 BR-W
38-50 O-W
1-25 BL-W
76-87 BR-W
51-62 G-W
63-75 G-W
100 PAIRS
4 BINDER GROUPS
26-50 O-W
126-150 BL-R
1-25 BL-W
51-75 G-W
101-125 S-W
76-100 BR-W
150 PAIRS
6 BINDER GROUPS
51-75 G-W
176-200 G-R
9-16 BL-W
76-100 BR-W
42-50 O-W
1-8 BL-W
17-25 BL-W
34-41 O-W
26-33 O-W
151-175 O-R
101-125 S-W
126-150 BL-R
200 PAIRS
8 BINDER GROUPS
ABBREVIATIONS:
BL - BLUE
O - ORANGE
G - GREEN
BR - BROWN
S - SLATE
W - WHITE
R - RED
BK - BLACK
Y - YELLOW
V - VIOLET

73.201.2
Figure 13-6.—Core makeup of one type of cable.

Table 13-1.—Binder Marking for 25 Pair Groups

Group No.	Color of Bindings	Group Pair Count
1	White-Blue	1 - 25
2	White-Orange	26 - 50
3	White-Green	51 - 75
4	White-Brown	76 - 100
5	White-Slate	101 - 125
6	Red -Blue	126 - 150
7	Red -Orange	151 - 175
8	Red -Green	176 - 200
9	Red -Brown	201 - 225
10	Red -Slate	226 - 250
11	Black-Blue	251 - 275
12	Black-Orange	276 - 300
13	Black-Green	301 - 325
14	Black-Brown	326 - 350
15	Black-Slate	351 - 375
16	Yellow-Blue	376 - 400

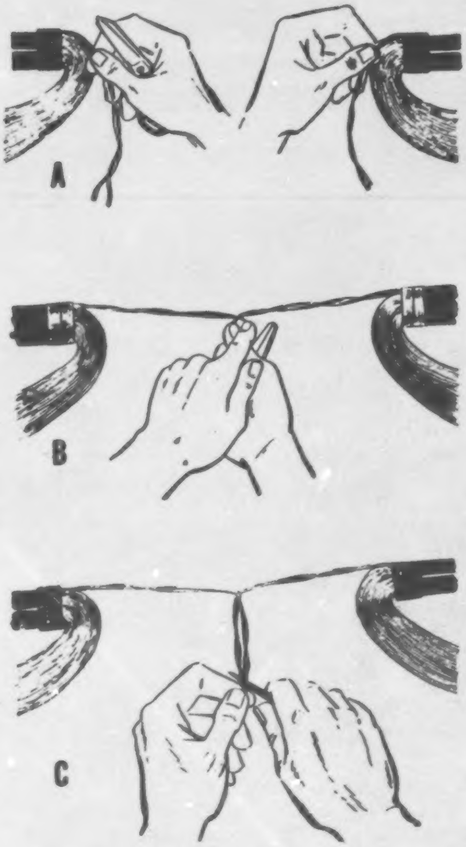
73.250

terminated on pair 101. When splicing non-color-coded cable, the conductor having red, green, or blue is the ring conductor and the white is the tip conductor.

Splicing the Wires

The pairs of wires are arranged within a cable in color groups, with low count at the center of the core and the higher count outside. The arrangement assists in quick identification. However, you should always work from a splicing diagram, or at least from definite identification instructions.

Lash the cable ends into convenient adjacent position, and fold the wires back as shown in figure 13-7, view A. Next, grasp a pair of wires from the right-hand cable end, the corresponding pair from the left-hand end, and give them a half-turn as shown in figure 13-7, view B. Then, holding both pairs of wires in one hand, cut them about 4 to 4 1/2 inches from the turn, as shown in figure 13-7, view C.



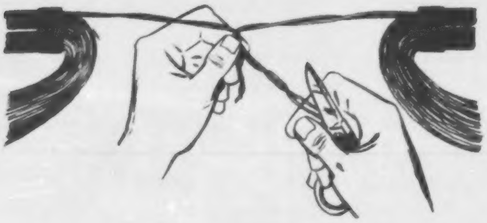
73.196

Figure 13-7.—Joining a pair of wires.

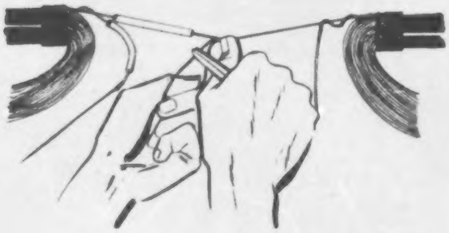
Before the splice can be made, the insulation must be stripped from the lengths of wires beyond the turn. As shown in figure 13-8, you grasp the wires just below the turn and pull the insulation off the ends. It is best to pull away from the turn and slightly toward the side on which you plan to slip the cotton sleeve. This will prevent the ends of the wires from curling.

Next you fit cotton sleeves onto both wires at the same time, slipping them over the wires. Use a rotating motion to slide the sleeves up to a position where they will not interfere with the splicing procedure.

Now bend one wire of each pair back out of the way and draw the other wires of each pair together as shown in figure 13-9. Draw the wires close together, so that the splicing twist can be



73.197
Figure 13-8.—Stripping insulation from wires.



73.198
Figure 13-9.—Drawing wires together for splicing.

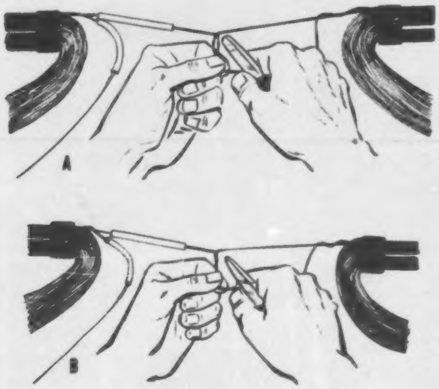
made close to the ends of the insulation. Then make the crank-handle twist shown in figure 13-10. First roll the left-hand wire over the right-hand one. Then bend them at right angles, and twist them together with a cranking motion of your wrist, until you get a twist about 1/2 inch long.

Bend or twist the pigtail, and cut off the excess wire. Then slip the sleeve down over the joint, as shown in figure 13-11.

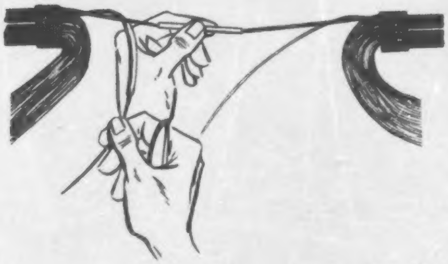
It is, of course, vitally important that you know what wires go together. However, it is always possible that you may have to do an emergency job where you don't have the necessary information in advance. In a case of this kind, a knowledge of the arrangement of groups in a cable will be of great value.

Placing and Wiping the Sleeve

After you have spliced all the pairs of conductors, wrap the splice bundle with two layers of dry muslin, as shown in figure 13-12. Slide the lead sleeve into place, exercising care to protect the cotton sleeves on the individual wire splices as well as the muslin wrap. This will prevent the wires from coming into contact with one another or with the lead sleeve.



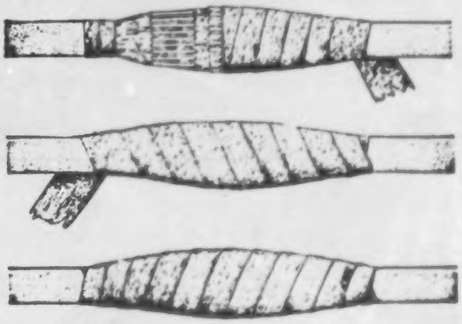
73.199
Figure 13-10.—Twisting the wires.



73.200
Figure 13-11.—Slipping the sleeve over the splice.

Unless you made your individual splices neatly and compactly, and unless you staggered them so they don't bunch up all at the same point, you will have difficulty getting the sleeve over the splice bundle.

The procedure for wiping the lead sleeve is the same as that described for a sleeve on a power cable in chapter 11.



73.202
Figure 13-12.—Wrapping the splice.

SPLICING SILK AND COTTON INSULATED CABLE

Paper ribbon or paper pulp insulation has certain disadvantages which make it unsuitable for use on cables to be connected to distribution frames, terminal strips, and other interior terminal points. The reason is that the paper insulation is not strong enough to withstand the amount of handling required to make connections. In working the core into a form which is fanned out and laced, the paper insulation, which is not baked on, will unroll. Besides, paper insulation deteriorates on exposure to air, and its dielectric strength falls off considerably on exposure to moisture.

It is the custom, therefore, to splice incoming paper-insulated cable onto short lengths of lead-covered textile-insulated (silk or cotton insulated) cables called cable heads. The heads are used to make the direct connections with central office distribution frames and terminal strips.

Prepare silk and cotton insulated cable for splicing by boiling out with beeswax, or with a special petroleum wax. Do not use paraffin, because it discolors the textile insulation, and makes it very difficult for the operator to separate conductors for fanning, forming, and splicing. On the other hand, do not use beeswax on paper-wrapped insulation, because it will make the paper brittle and may cause breakage.

Start pouring the wax a few inches back on the sheath, and gradually advance toward the exposed conductors. To start at the conductors and go the other way would defeat the purpose of boiling out by forcing any moisture under the sheath further back.

The same standard splice openings, number of cotton sleeve banks, and splicing procedures apply to textile-insulated change cables as apply to paper-insulated exchange cables. When splicing silk and cotton insulated cable to paper-wrapped insulated cable, use a desiccant for drying out the joint.

Mark the point for removal of textile insulation by the same procedure described for paper-insulated cables. Cut off the conductors 4 1/2 inches from the end and use long-nosed pliers to crush the silk/cotton insulation at the marked point. Don't apply too much pressure, because this will flatten the conductor and may cuase it to break after splicing. After the insulation has been crushed, it can be removed by decreasing the pressure on the pliers and skinning the insulation off by pulling toward the end in a straight line. However, if you prefer you can pull it off with the fingers. Never use the back of the splicing scissors to remove insulation; this might break the relatively brittle tinned-copper conductors in a textile-insulated cable.

Some textile-insulated cables have enameled conductors, and this enamel must be thoroughly removed before the wires can be spliced. One method is by light scraping between the jaws of long-nosed pliers—but you must be extremely careful not to nick or flatten the wires.

A good tool for scraping enamel is the wire scraper, which consists of a steel spring 3/4 inch wide, bent in the form of a U and with ends turned and sharpened. As you gain skill with this tool, you will find it effective for removing silk, cotton, of plastic insulation.

Twist the conductors by using the same twist described for splicing paper-insulated cable. After the splice is completed, boil out with hot paraffin or dry with desiccant as you would a paper-insulated splice.

SPLICING POLYETHYLENE-INSULATED CABLE

Polyethylene-insulated cable (PIC) (polyethylene is commonly called plastic) is available as aerial or as direct burial cable, both types being made in even-numbered pairs. The cores of both types are identical, in that they are fully coded—meaning that each pair in the cable is distinguishable by color from every other pair. This is accomplished by the use of a color scheme which provides different colors of insulation for each pair in a 25-pair group, together with colored or imprinted bindings to distinguish 25-pair groups from each other. By referring to tables which give pair color codes, binder markings and possible layups, you can match the wires in one of these cables with little difficulty. See table 13-2.

PIC has solid copper conductors, each with polyethylene insulation of the required color. The insulated conductors are twisted into pairs. The required number of pairs are stranded into a cable core and enclosed in a metallic shield and polyethylene jacket or sheath.

In cables having 25 pairs or less, the twisted pairs are assembled to form a substantially cylindrical core. In cables having more than 25 pairs, the twisted pairs are arranged in groups, each group being bound by moisture-resistant thread or tape. Each group contains not more than 25 pairs. For layup purposes, the basic 25-pair groups may be divided into two or more subgroups called units.

Each unit in a particular 25-pair group is enclosed in bindings of the colors indicated for its particular 25-pair group. For example: suppose you have a 100-pair cable and are looking for pair number 88. You look for the group with binding colors white and brown; then look for the pair in that particular group with black and green insulation (see fig. 13-6 and table 13-3).

The aerial-type cable has an aluminum shield applied longitudinally over the core covering. The seam in this shield is joined during the manufacturing process by means of a cold weld, and electric weld, or soldering with a nonacid flux. A polyethylene jacket is then placed over the shield.

The direct-burial type cable has two polyethylene jackets with a copper shield between the inner and outer jacket. The inner jacket is placed over the completed core, and is from 50 to 70 mils thick according to the number of pairs in the cable. The outer jacket, placed over the shield, is from 40 to 80 mils thick.

SPLICING POLYETHYLENE CABLE FOR AERIAL INSTALLATION

The procedure for splicing polyethylene cable for use in aerial installation is described in following paragraphs. A point to note is that the main difference between a splice in polyethylene cable and one in other types of cable is in the method of enclosing the splice. A splice in polyethylene cable is enclosed in a polyethylene or neoprene enclosure unit consisting of a base assembly and a rubber or polyethylene cover which snaps in place over it, whereas a splice in other types is enclosed in a metal or plastic sleeve.

Removing the Sheath

The length of the opening in the cable sheath varies according to the type of closure and the size of the cable. Steps in removing the sheath are as follows:

1. After determining the length of the opening from the manufacturer's instructions, place three wraps of vinyl tape around the sheath at each end of the proposed opening to mark the ends, as shown in figure 13-13.

2. Ring the sheath carefully 3 inches from the splice opening marker tapes, as also shown in figure 13-13.

3. Remove the sheath between the two rings.

4. Remove the shield in the same area, as shown in figure 13-14.

5. Cut tabs in the jacket and shield in the 3-inch space between opening and marker tapes as shown in figure 13-15. Cut 3 tabs for cable up to 0.6 inch in diameter, 4 for cable from 0.6 to 1.6 inches in diameter, and 6 for cable from 1.6 to 2.2 inches in diameter.

6. Enlarge slot to 1/8 inch as also shown in figure 13-15.

7. Place two turns of vinyl tape, adhesive side out, then one turn with adhesive side in, as shown in figure 13-16. Push these wraps of tape under tabs as shown, to form a base for the clamps of the base assembly to be installed later.

8. Place two turns of vinyl tape to hold the core wrapper in place at the ends of the tabs, and remove the core wrapper.

Table 13-2.—Possible Layups of Polyethylene Insulated Cables With Standard Telephone Color Code

Size	Center			First Layer			Second Layer		
Pairs in Cable	Pairs in Unit	Binder Colors	Pair Count	Pairs in Unit	Binder Colors	Pair Count	Pairs in Unit	Binder Colors	Pair Count
50	8	White-Blue	1-8	9	White-Blue	9-17			
				8	White-Blue	18-25			
				8	White-Orange	26-33			
				9	White-Orange	34-42			
				8	White-Orange	43-50			
75	12	White-Blue	1-12	13	White-Blue	13-25			
				12	White-Orange	26-37			
				13	White-Orange	38-50			
				12	White-Green	51-62			
				13	White-Green	63-75			
100	25	White-Blue	1-25	12	White-Orange	26-37			
				13	White-Orange	38-50			
				12	White-Green	51-62			
				13	White-Green	63-75			
				12	White-Brown	76-87			
				13	White-Brown	88-100			
150	25	White-Blue	1-25	25	White-Orange	26-50			
				25	White-Green	51-75			
				25	White-Brown	76-100			
				25	White-Slate	101-125			
				25	Red-Blue	126-150			
200	8	White-Blue	1-8	9	White-Blue	9-17	25	White-Green	51-75
				8	White-Blue	18-25	25	White-Brown	76-100
				8	White-Orange	26-33	25	White-Slate	101-125
				9	White-Orange	34-42	25	Red-Blue	126-150
				8	White-Orange	43-50	25	Red-Orange	151-175
							25	Red-Green	176-200
300	25	White-Blue	1-25	25	White-Brown	76-100			
	25	White-Orange	26-50	25	White-Slate	101-125			
	25	White-Green	51-75	25	Red-Blue	126-150			
				25	Red-Orange	151-175			
				25	Red-Green	176-200			
				25	Red-Brown	201-225			
				25	Red-Slate	226-250			
				25	Black-Blue	251-275			
				25	Black-Orange	276-300			
400	25	White-Blue	1-25	25	White-Orange	26-50	25	Red-Orange	151-175
				25	White-Green	51-75	25	Red-Green	176-200
				25	White-Brown	76-100	25	Red-Brown	201-225
				25	White-Slate	101-125	25	Red-Slate	226-250
				25	Red-Blue	126-150	25	Black-Blue	251-275
							25	Black-Orange	276-300
							25	Black-Green	301-325
							25	Black-Brown	326-350
							25	Black-Slate	351-375
							25	Yellow-Blue	376-400

73.251

Table 13-3.—Color Code For Plastic-Insulated Conductor Cables

Pair No.	Group binder		Color of insulation	
			Tip	Ring
1	Blue	White	White	Blue
2	Blue	White	White	Orange
3	Blue	White	White	Green
4	Blue	White	White	Brown
5	Blue	White	White	Slate
6	Blue	White	Red	Blue
7	Blue	White	Red	Orange
8	Blue	White	Red	Green
9	Blue	White	Red	Brown
10	Blue	White	Red	Slate
11	Blue	White	Black	Blue
12	Blue	White	Black	Orange
13	Blue	White	Black	Green
14	Blue	White	Black	Brown
15	Blue	White	Black	Slate
16	Blue	White	Yellow	Blue
17	Blue	White	Yellow	Orange
18	Blue	White	Yellow	Green
19	Blue	White	Yellow	Brown
20	Blue	White	Yellow	Slate
21	Blue	White	Violet	Blue
22	Blue	White	Violet	Orange
23	Blue	White	Violet	Green
24	Blue	White	Violet	Brown
25	Blue	White	Violet	Slate
26	Orange	White	White	Blue
50	Orange	White	Violet	Slate
51	Green	White	White	Blue
52	Green	White	White	Orange
74	Green	White	Violet	Brown
75	Green	White	Violet	Slate
76	Brown	White	White	Blue
77	Brown	White	White	Orange
99	Brown	White	Violet	Brown
100	Brown	White	Violet	Slate

73.338

Identifying Binder Groups

Upon removing the core wrapper, have ready some short pieces of paired conductors with colors matching the color code of the binder groups. Place a matching color pair around each binder group and pigtail the ends of the tie wires. The binder threads or tape can then be removed from the binder groups.

Mount the base assembly for the ready-access closure. The tape which was placed to mark the splice opening may then be removed.

Place the groups in a convenient position, so you can proceed with splicing the conductors.

Splicing the Conductors

Figure 13-17 shows one method of splicing the conductors, a method which includes the use of a plastic-filled sleeve. This method requires that the wires first be twisted with three loose turns. Strip off the insulation and make five firm half-turns, cut off the excess wire leaving about 1 inch of twisted bare wires, and solder with resin core solder. Then slip the filled sleeve over the joint and bend the splice into position.

Figure 13-18 shows the use of a sealing-type splicing connector. The conductors are twisted enough to hold the pair of wires together, and the connector is slipped over the ends of the wires approximately 3 inches from the beginning of the twist. A hand-operated crimping tool is used to crimp the connector. DO NOT remove the insulation from the ends of the wires when using this method, because the insulation on the wires keeps the conductors centered in the connector.

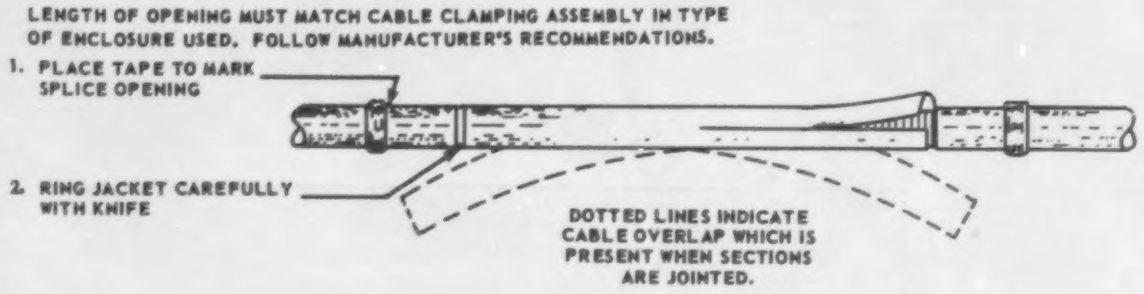
When a pair of conductors dead end in a splice, turn back 3/4 inch of one conductor and place a filled plastic sleeve over the end of the pair of conductors, as indicated in figure 13-18.

Layup of Spliced Conductors

The number of splice bundles required for a convenient layup will depend on the length of the splice opening and the size of the cable. The splices must be placed in uniform bundles and distributed to give a uniform shape to the full length of the splice area. After the bundle is completed, it should be bound with layers of vinyl tape. Figure 13-19 shows a well-shaped splice bundle.

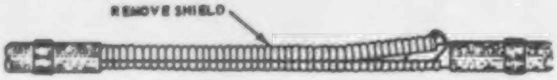
Closing the Splice

After the splices are complete and the bundles are taped, the closure is spread open, slipped


LENGTH OF OPENING MUST MATCH CABLE CLAMPING ASSEMBLY IN TYPE OF ENCLOSURE USED. FOLLOW MANUFACTURER'S RECOMMENDATIONS.
1. PLACE TAPE TO MARK SPLICE OPENING
2. RING JACKET CAREFULLY WITH KNIFE
DOTTED LINES INDICATE CABLE OVERLAP WHICH IS PRESENT WHEN SECTIONS ARE JOINTED.

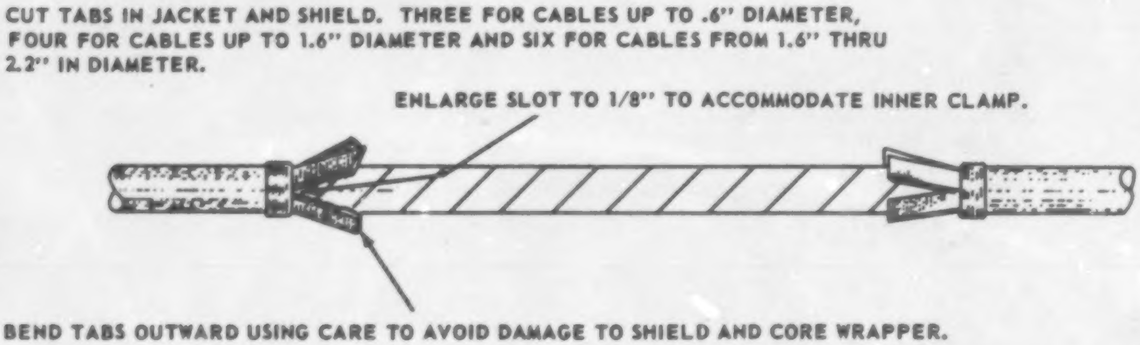
73.204

Figure 13-13.—Splicing opening in polyethylene cable.


REMOVE SHIELD

73.205

Figure 13-14.—Removing the shield.


CUT TABS IN JACKET AND SHIELD. THREE FOR CABLES UP TO .6" DIAMETER, FOUR FOR CABLES UP TO 1.6" DIAMETER AND SIX FOR CABLES FROM 1.6" THRU 2.2" IN DIAMETER.
ENLARGE SLOT TO 1/8" TO ACCOMMODATE INNER CLAMP.
BEND TABS OUTWARD USING CARE TO AVOID DAMAGE TO SHIELD AND CORE WRAPPER.

73.206

Figure 13-15.—Cutting tabs in jacket and shield.

over the bundle and snapped in place over the entire assembly. This closure is made of polyethylene or neoprene, and when it is placed over the splice assembly in the proper manner and fastened with the clips which come with the kit, the splice will be completely weatherproof, but still easily accessible should the need arise to reopen the closure.

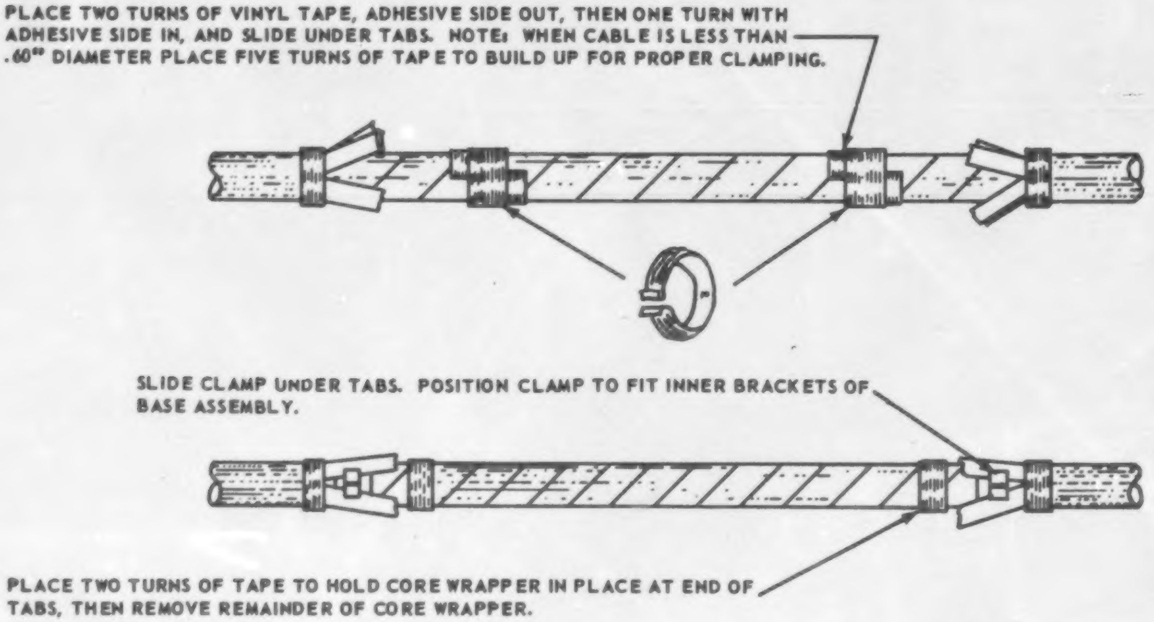
Figure 13-20 shows two splice closures in place. The cables leaving the lower nipples run to terminal closures on other poles. Figure 13-21 shows the parts of a closure. When fewer than four cables are brought out, the openings in the nipples not being used are plugged with plugs made for the purpose.

Figure 13-22 shows a closure made for terminal blocks. When only one cable enters, the vacant nipple is plugged.

SPLICING PLASTIC-SHEATHED CABLE TO LEAD-SHEATHED CABLE

The method described here for joining plastic-sheathed, plastic-insulated cable to lead-sheathed, paper-insulated cable may be used on aerial, direct-burial, or duct installations. The method is illustrated in figures 13-23, 13-24, and 13-25.

First mark the cable sheath with the location of the splice and place additional marks a



PLACE TWO TURNS OF VINYL TAPE, ADHESIVE SIDE OUT, THEN ONE TURN WITH ADHESIVE SIDE IN, AND SLIDE UNDER TABS. NOTE: WHEN CABLE IS LESS THAN .60" DIAMETER PLACE FIVE TURNS OF TAPE TO BUILD UP FOR PROPER CLAMPING.

SLIDE CLAMP UNDER TABS. POSITION CLAMP TO FIT INNER BRACKETS OF BASE ASSEMBLY.

PLACE TWO TURNS OF TAPE TO HOLD CORE WRAPPER IN PLACE AT END OF TABS, THEN REMOVE REMAINDER OF CORE WRAPPER.

73.207

Figure 13-16.—Placing clamps under tabs.

standard distance on either side (4 inches on lead, 7 inches on plastic). With aerial-type cable, the cable on either side of the splice should lie along the suspension strand without tension when the strand is at normal tension. The length of the splice opening and the size of the lead sleeve required are shown in figure 13-23.

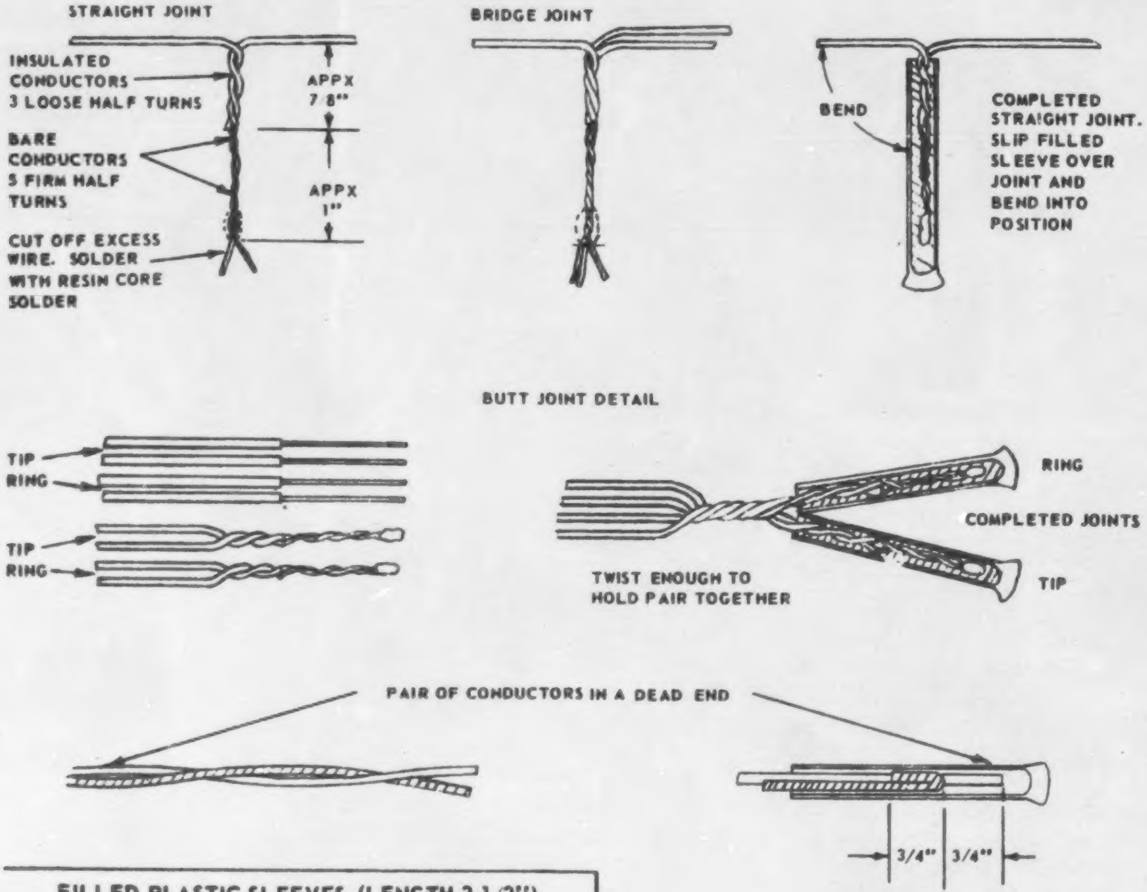
On the lead sheath end, carefully remove the desired amount of sheath so that the core wrapper or the insulation around the conductors will not be damaged. Scrape the surface of the lead 4 inches from the point where the sheath was cut, making sure to remove all dull spots and streaks to present a clean surface for wiping the lead joint. Coat this cleaned space with stearine. Then remove the core wrapper from the exposed cable.

On the plastic cable end, remove the sheath carefully for the desired distance so that the metal shield, the core wrapper, and the insulation around the conductors will not be damaged. Scuff the sheath of the cable for a distance of 7 inches from the opening, using No. 2 1/2 grade sandpaper. Do not use emery paper or cloth. This scuffing will ensure a satisfactory surface for the proper adhesion of the end seal casting and for the subsequent taping operations. Turn back the shield and remove the core wrapper to the end of the sheath opening.

Select a lead sleeve of proper size. Clean the outside of the sleeve for a distance of 7 inches from the end toward the plastic-sheathed cable, and for a distance of 2 inches from the end toward the lead-sheathed cable. Place the sleeve over the lead-sheathed cable and push it back out of the way until needed, as shown in figure 13-23.

Casting the Plastic End Seal

Prepare a cone-shaped casting form (one may be made from a cone-shaped paper cup or something similar). Be sure that the largest diameter of the form is not larger than the inside diameter of the lead sleeve being used. Fashion a hole in the bottom of the form to make a snug fit over the plastic-cable sheath. Slide the form over the sheath to a temporary position about 4 inches back from the end of the


STRAIGHT JOINT
INSULATED CONDUCTORS 3 LOOSE HALF TURNS
APPX 7/8"
BARE CONDUCTORS 5 FIRM HALF TURNS
APPX 1"
CUT OFF EXCESS WIRE. SOLDER WITH RESIN CORE SOLDER
BRIDGE JOINT
BEND
COMPLETED STRAIGHT JOINT. SLIP FILLED SLEEVE OVER JOINT AND BEND INTO POSITION
BUTT JOINT DETAIL
TIP
RING
TIP
RING
RING
COMPLETED JOINTS
TIP
TWIST ENOUGH TO HOLD PAIR TOGETHER
PAIR OF CONDUCTORS IN A DEAD END
3/4"
3/4"

TURN BACK ONE CONDUCTOR OF PAIR AND CAP WITH FILLED PLASTIC SLEEVE. POSITION SLEEVE FOR POSSIBLE FUTURE SPLICING.

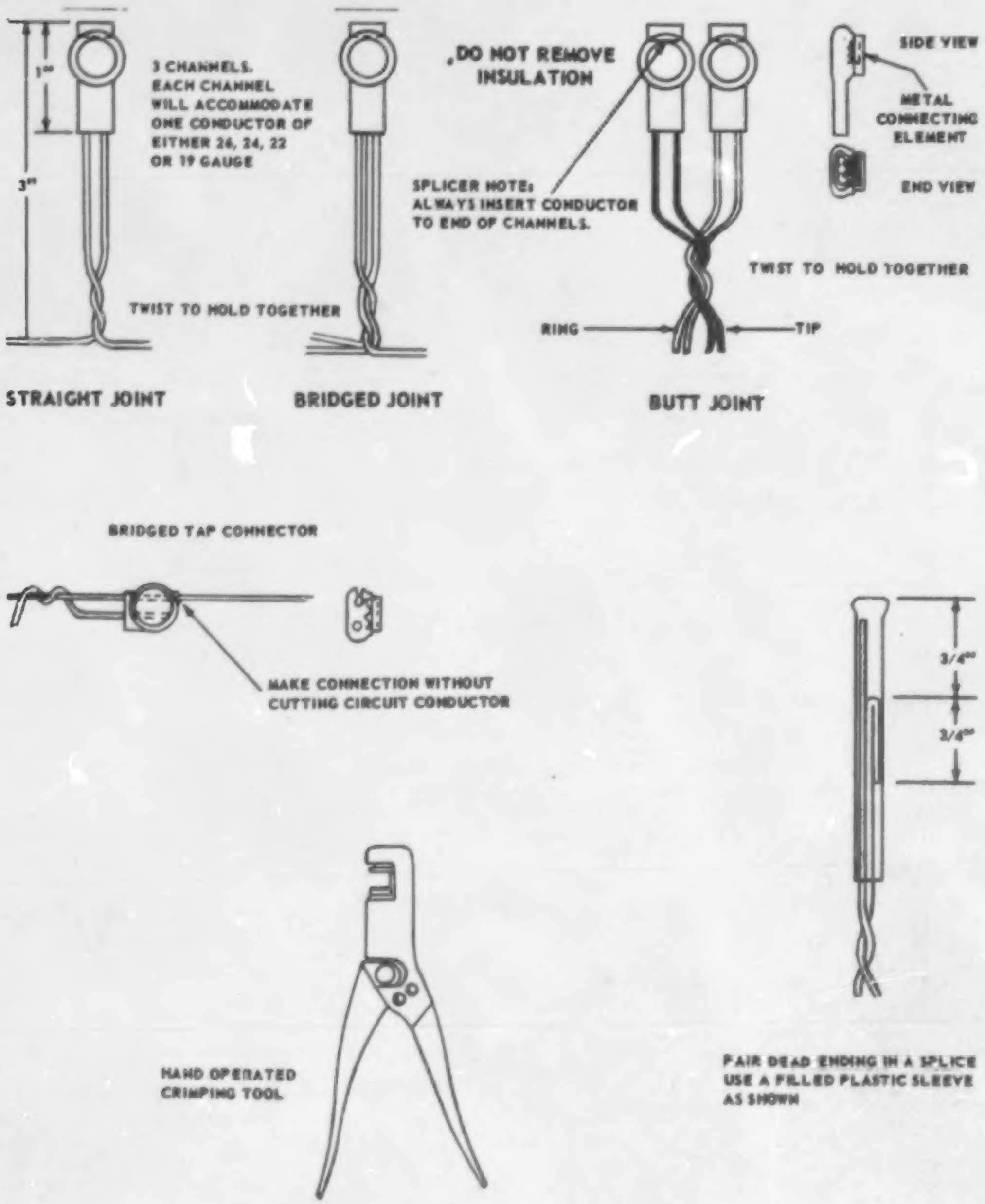
PRECAUTION: TO AVOID CRACKING AND LOSS OF FILLER, THE PROPER SIZE SLEEVES SHOULD BE USED AND NOT FORCED OVER JOINTS.

FILLED PLASTIC SLEEVES (LENG~~TH 2~~-1/2")

GAUGE OF CONDUCTORS	TYPE OF JOINTS	INSIDE DIAMETER	COLOR
24X24	STRAIGHT	.085	YELLOW
24X22		.085	"
24X19		.105	GREEN
22X22		.105	"
22X19		.105	"
19X19		.125	CLEAR
24X24X24	BRIDGE	.085	YELLOW
24X24X22		.105	GREEN
24X24X19		.105	"
22X22X24		.105	"
22X22X22		.105	"
22X22X19		.125	CLEAR
19X19X24		.125	"
19X19X22		.125	"
19X19X19		.145	RED

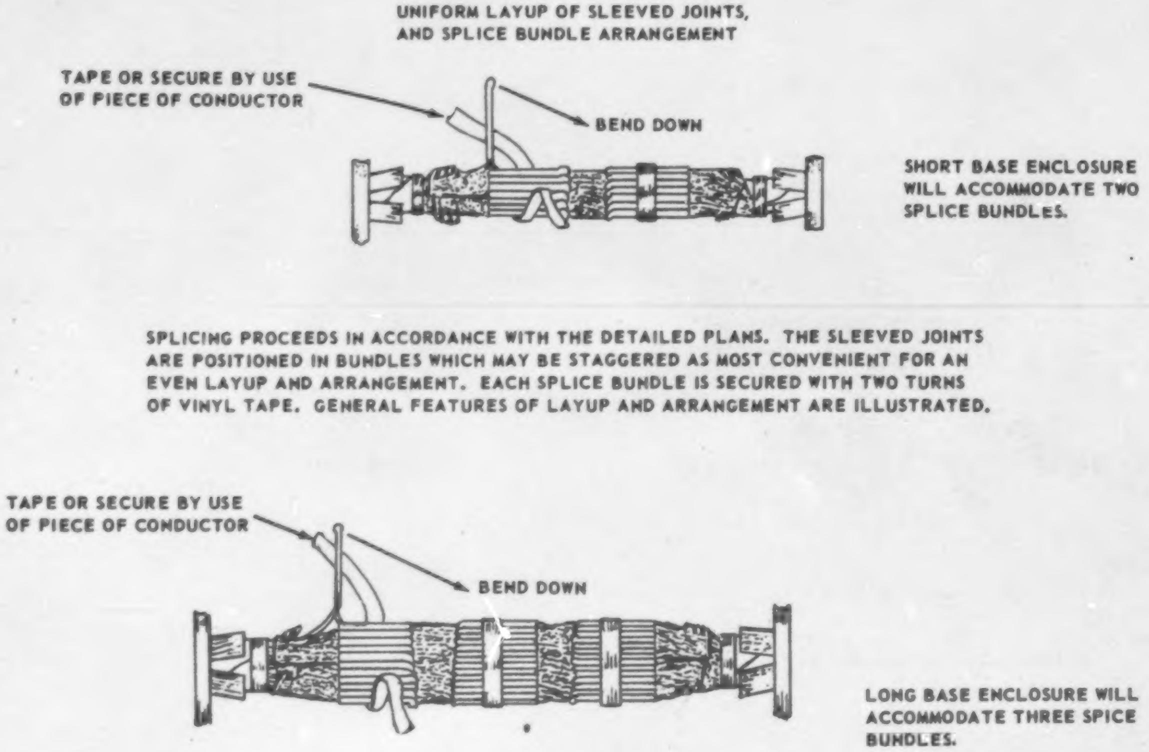
73.208

Figure 13-17.—Splicing details for various types of joints.


1"
3"
3 CHANNELS.
EACH CHANNEL
WILL ACCOMMODATE
ONE CONDUCTOR OF
EITHER 26, 24, 22
OR 19 GAUGE
TWIST TO HOLD TOGETHER
STRAIGHT JOINT
BRIDGED JOINT
DO NOT REMOVE
INSULATION
SPLICER NOTE:
ALWAYS INSERT CONDUCTOR
TO END OF CHANNELS.
SIDE VIEW
METAL
CONNECTING
ELEMENT
END VIEW
TWIST TO HOLD TOGETHER
RING
TIP
BUTT JOINT
BRIDGED TAP CONNECTOR
MAKE CONNECTION WITHOUT
CUTTING CIRCUIT CONDUCTOR
3/4"
3/4"
HAND OPERATED
CRIMPING TOOL
PAIR DEAD ENDING IN A SPLICE
USE A FILLED PLASTIC SLEEVE
AS SHOWN

73.209

Figure 13-18.—Sealing-type splicing connector.


UNIFORM LAYUP OF SLEEVED JOINTS, AND SPLICE BUNDLE ARRANGEMENT
TAPE OR SECURE BY USE OF PIECE OF CONDUCTOR
BEND DOWN
SHORT BASE ENCLOSURE WILL ACCOMMODATE TWO SPLICE BUNDLES.
TAPE OR SECURE BY USE OF PIECE OF CONDUCTOR
BEND DOWN
LONG BASE ENCLOSURE WILL ACCOMMODATE THREE SPICE BUNDLES.

SPLICING PROCEEDS IN ACCORDANCE WITH THE DETAILED PLANS. THE SLEEVED JOINTS ARE POSITIONED IN BUNDLES WHICH MAY BE STAGGERED AS MOST CONVENIENT FOR AN EVEN LAYUP AND ARRANGEMENT. EACH SPLICE BUNDLE IS SECURED WITH TWO TURNS OF VINYL TAPE. GENERAL FEATURES OF LAYUP AND ARRANGEMENT ARE ILLUSTRATED.

73.210

Figure 13-19.—Layup pattern for splice.

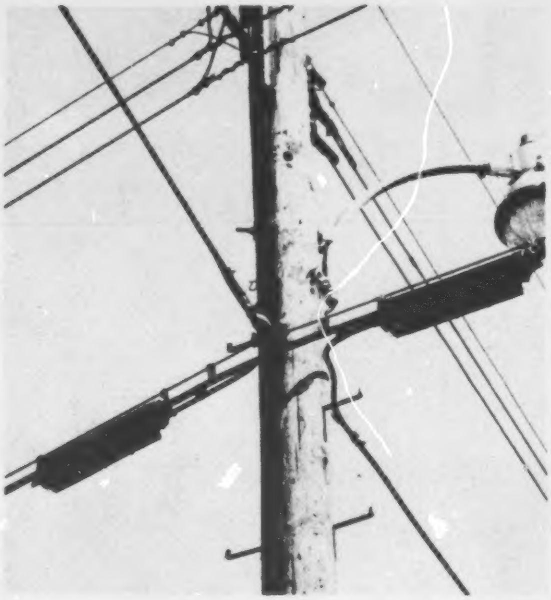
sheath. Turn up the end of the cable and secure it in a vertical position for the casting operation. Spread the conductors to allow space for the casting liquid to completely seal all voids.

Move the casting form up until it extends about 1/2 inch above the end of the plastic sheath. If the lower end of the form is not tight around the sheath, it may be necessary to use a few wraps of tape to hold it in position and seal any openings. Figure 13-23 shows a form in place.

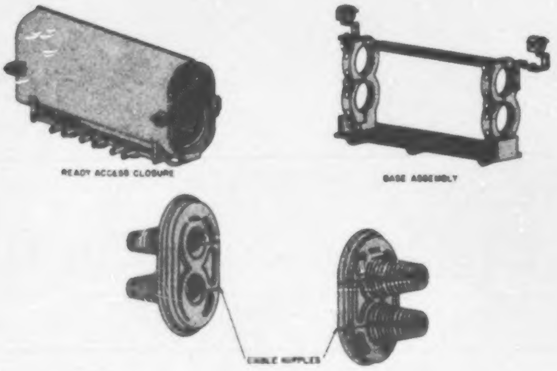
Prepare the casting mixture according to instructions included with the container. You will notice that the casting resin will develop heat immediately after being mixed, but this heat will not cause any harm. When the mixture is ready to pour, pour it into the form until it reaches a point very close to the top. During the pouring process, move the wires and shield slightly to aid penetration and to bring the shield and wires into alignment for the splicing operation. After the form is filled, allow the mixture to harden for approximately 10 minutes, or until it is firm and cool to the touch. Then peel off the form and clean off any particles that may have adhered to the casting. The cable then may be bent back into position for the splicing operation.

Splicing and Soldering Conductors

Separate conductors into bunches by color groups or complements, and secure them in a convenient position for splicing, leaving a suitable length for staggered spacing of splices to attain a uniform layup. Excess wire should then be cut off. As conductors are selected for splicing, plastic sleeves of proper diameter should be placed over one of the conductors and pushed back. Where conductors end in a splice, cut them off and place a sleeve (selected according to fig. 13-24 specifications) over the



73.211
Figure 13-20.—Splice closures in place.



73.212X
Figure 13-21.—Parts of a splice closure.

ends and position it for subsequent use. All sleeves are 3 inches long.

Remove the required length of insulation from the conductors as they are selected for splicing. Twist the individual, skinned conductors together. Make a joint 1 3/8 inches to 1 3/4 inches in length, starting with three loose half-turns (about 1 inch), then finishing with five tight half-turns (about 3/8 to 1/2 inch).

After the excess wire has been cut off, solder the joint using resin core solder. Bend the soldered pigtail into place, and slide the previously placed sleeve over the joint, as shown in figure 13-24.

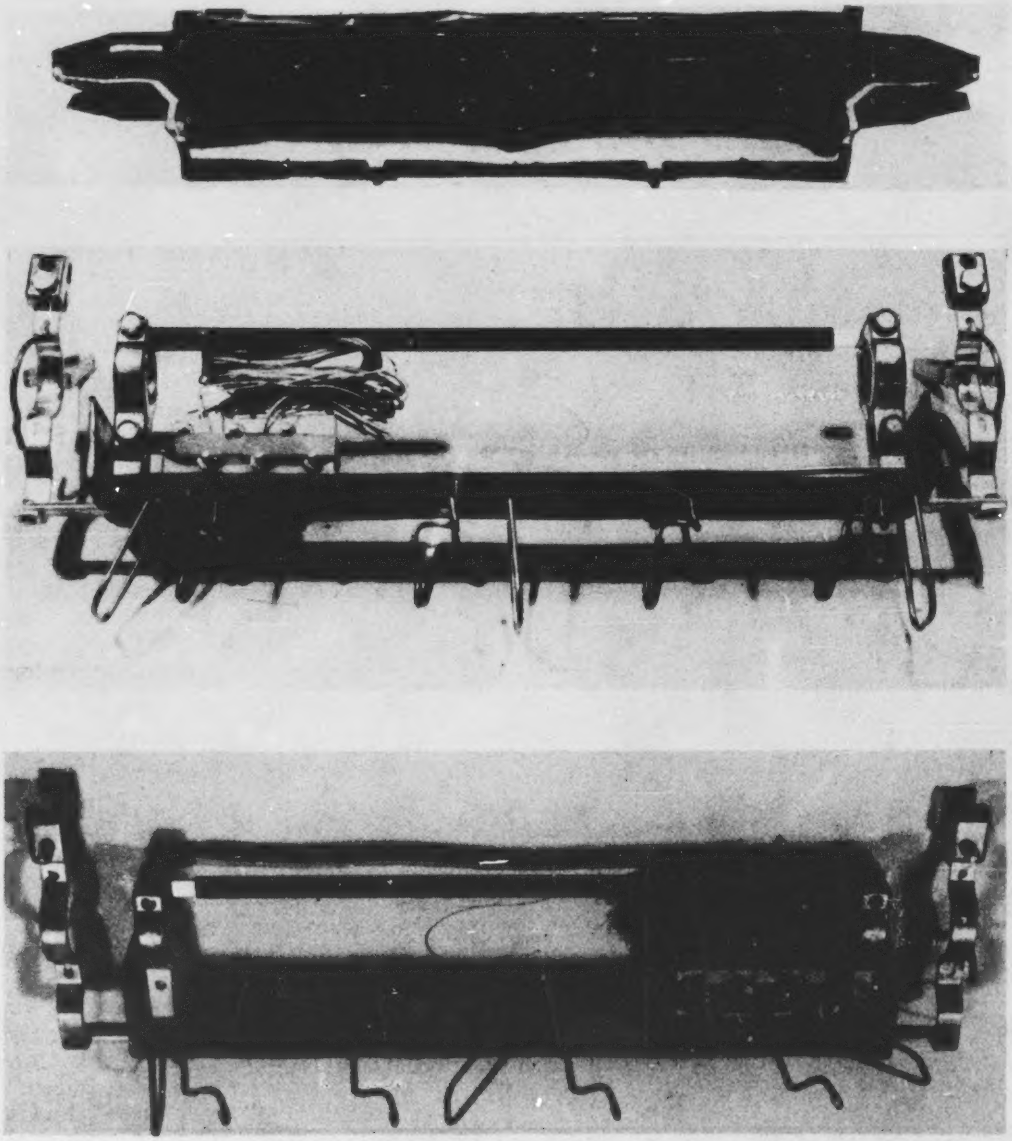
After all conductors have been spliced and placed in the proper layup, wrap the body of the splice with a plastic envelope cut from a sheet of polyethylene or the equivalent. Fill the envelope with desiccant in amounts for various sizes of cable as shown in figure 13-24. BE SURE NOT TO EXCEED THE RECOMMENDED AMOUNTS.

Cover the whole splice with a single layer of half-lapped-vinyl tape, but do not overlap the cable sheath or metallic shield. To ensure continuity of the shield, rewrap the shielding material around the splice, extending in onto the lead sheath. If the shield material is not long enough to make a full wrap around the lead sheath, add an extra piece of shielding and solder it to the existing strip. This soldering operation should be performed away from the cable core to protect the tape from the heat of the soldering iron. Solder the end of the shield to the lead sheath at the point of overlap. On aerial-type plastic cable, tin the aluminum shield with Alcoa 64 aluminum flux and solder it with 50-50 or resin core solder.

Placing the Sleeve

Place a strip of tape on the plastic sheath extending lengthwise about 2 1/2 inches from the base of the cast end seal, as shown in figure 13-25. Secure a strip of wire cloth 2 inches wide, starting the edge of the wire cloth on the strip of tape and wrapping tightly around the cable, overlapping the starting point about 1 inch.

Secure the edges of the wire cloth in place with tape. Hold a hot soldering iron firmly against the wire cloth at numerous points around the sheath until dark patches appear through the wire mesh. This operation will, by softening the plastic, anchor the wire cloth in the plastic sheath. Be careful not to hold the iron too long in one place, or the insulation may be burned.

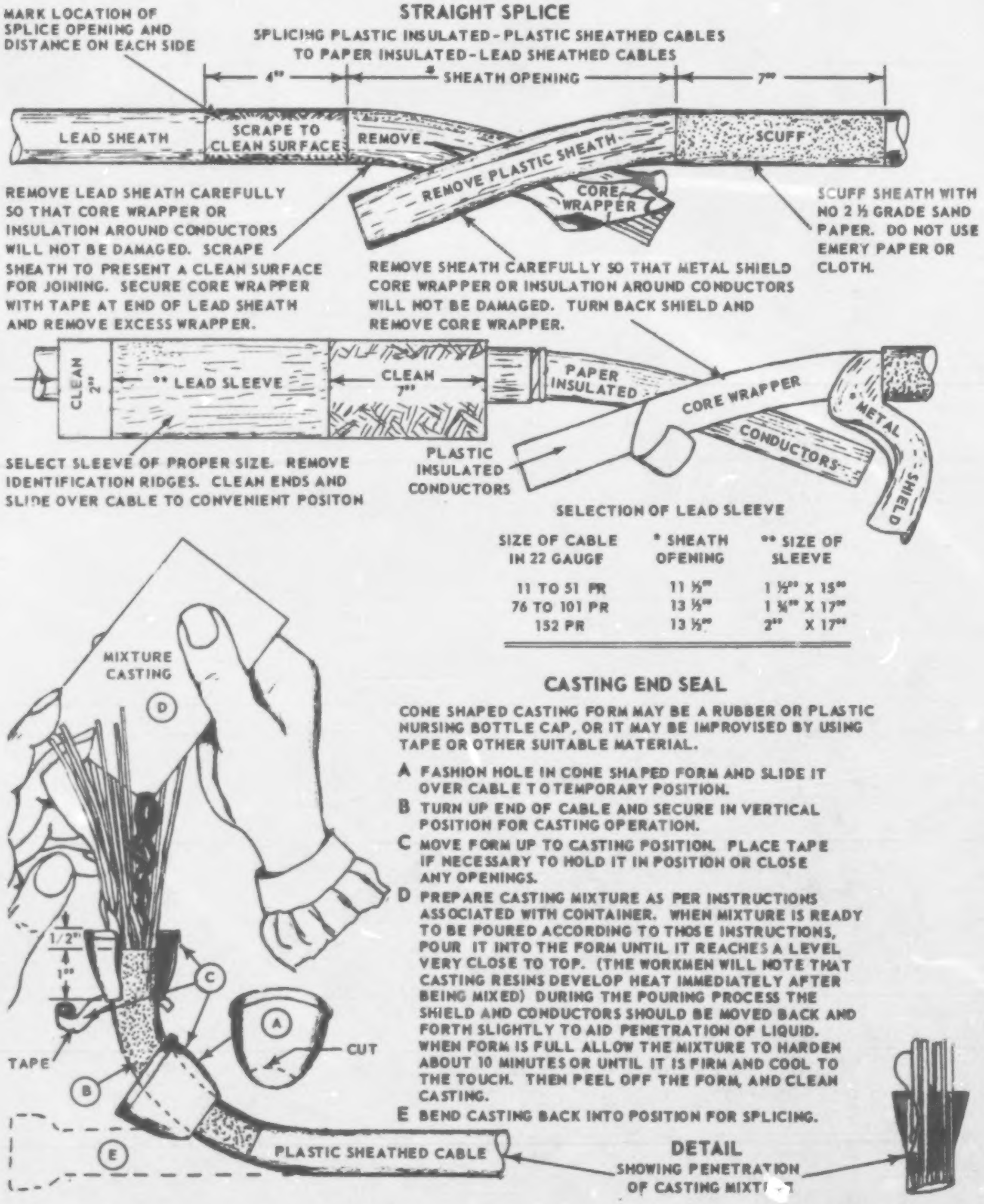


73.213

Figure 13-22.—Terminal-block closure.

Place the lead sleeve in position over the splice, overlapping the lead-cable sheath about 1 1/2 inches, and overlapping the wire cloth on the plastic sheath about 1 inch. Beat in the end of the sleeve on the lead-sheath side and wipe in the usual manner.

On the plastic-sheath side, shape the end of the lead sleeve to the copper-wire cloth in a gradually tapering slope. This will tend to make the taping operation easier. Solder the lead sleeve to the wire cloth, using resin-core solder and a soldering copper.


4"
* SHEATH OPENING
7"
LEAD SHEATH
SCRAPE TO CLEAN SURFACE
REMOVE
REMOVE PLASTIC SHEATH
CORE WRAPPER
SCUFF
CLEAN 2"
** LEAD SLEEVE
CLEAN 7"
PAPER INSULATED
CORE WRAPPER
CONDUCTORS
METAL SHIELD
PLASTIC INSULATED CONDUCTORS
MIXTURE CASTING
D
1/2"
1"
C
A
CUT
TAPE
B
E
PLASTIC SHEATHED CABLE

STRAIGHT SPLICE

SPLICING PLASTIC INSULATED-PLASTIC SHEATHED CABLES TO PAPER INSULATED-LEAD SHEATHED CABLES

MARK LOCATION OF SPLICE OPENING AND DISTANCE ON EACH SIDE

REMOVE LEAD SHEATH CAREFULLY SO THAT CORE WRAPPER OR INSULATION AROUND CONDUCTORS WILL NOT BE DAMAGED. SCRAPE SHEATH TO PRESENT A CLEAN SURFACE FOR JOINING. SECURE CORE WRAPPER WITH TAPE AT END OF LEAD SHEATH AND REMOVE EXCESS WRAPPER.

REMOVE SHEATH CAREFULLY SO THAT METAL SHIELD CORE WRAPPER OR INSULATION AROUND CONDUCTORS WILL NOT BE DAMAGED. TURN BACK SHIELD AND REMOVE CORE WRAPPER.

SCUFF SHEATH WITH NO 2 ½ GRADE SAND PAPER. DO NOT USE EMERY PAPER OR CLOTH.

SELECT SLEEVE OF PROPER SIZE. REMOVE IDENTIFICATION RIDGES. CLEAN ENDS AND SLIDE OVER CABLE TO CONVENIENT POSITON

SELECTION OF LEAD SLEEVE

SIZE OF CABLE IN 22 GAUGE	* SHEATH OPENING	** SIZE OF SLEEVE
11 TO 51 PR	11 ½"	1 ½" X 15"
76 TO 101 PR	13 ½"	1 ¾" X 17"
152 PR	13 ½"	2" X 17"

CASTING END SEAL

CONE SHAPED CASTING FORM MAY BE A RUBBER OR PLASTIC NURSING BOTTLE CAP, OR IT MAY BE IMPROVISED BY USING TAPE OR OTHER SUITABLE MATERIAL.

A FASHION HOLE IN CONE SHAPED FORM AND SLIDE IT OVER CABLE TO TEMPORARY POSITION.

B TURN UP END OF CABLE AND SECURE IN VERTICAL POSITION FOR CASTING OPERATION.

C MOVE FORM UP TO CASTING POSITION. PLACE TAPE IF NECESSARY TO HOLD IT IN POSITION OR CLOSE ANY OPENINGS.

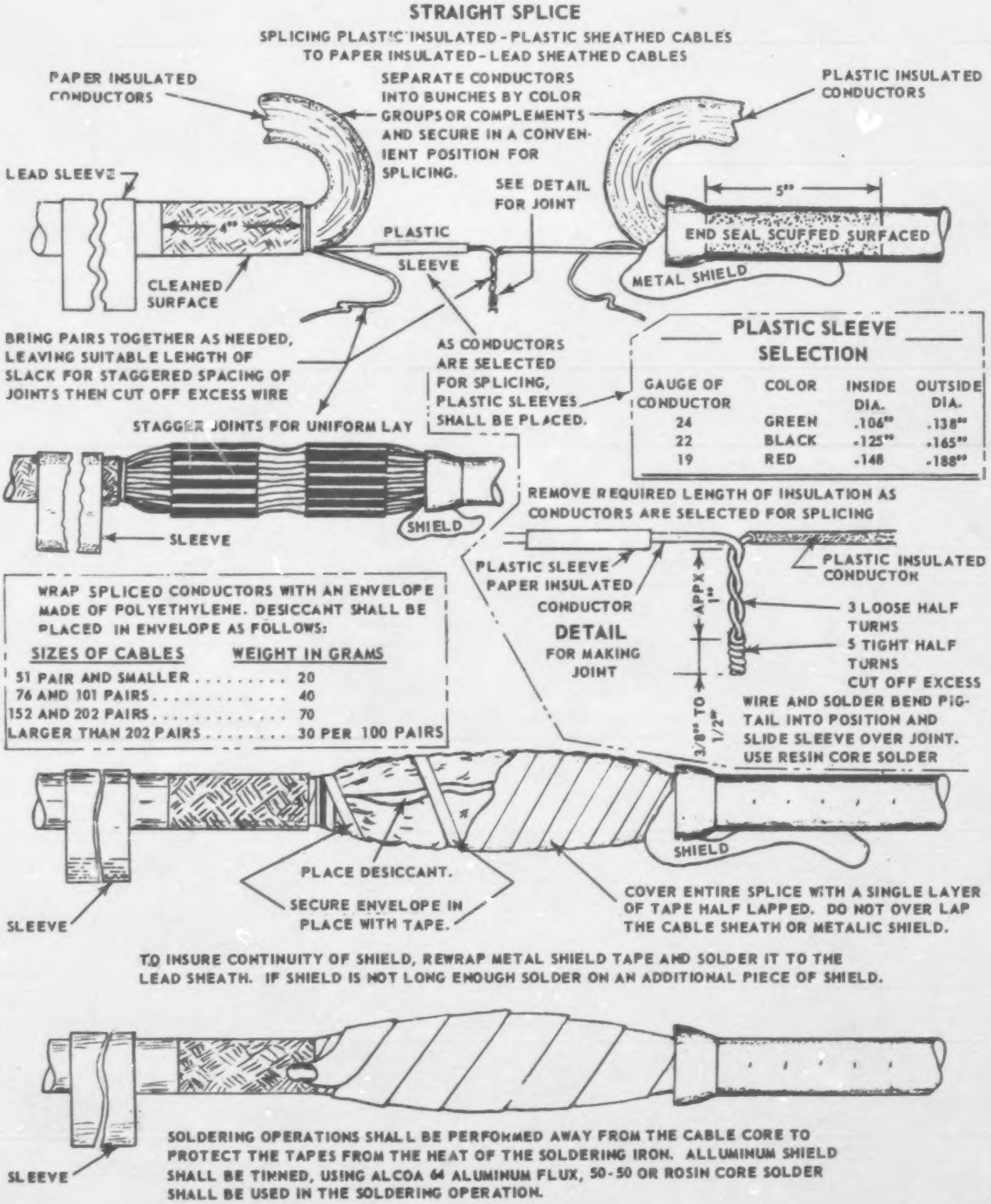
D PREPARE CASTING MIXTURE AS PER INSTRUCTIONS ASSOCIATED WITH CONTAINER. WHEN MIXTURE IS READY TO BE POURED ACCORDING TO THOSE INSTRUCTIONS, POUR IT INTO THE FORM UNTIL IT REACHES A LEVEL VERY CLOSE TO TOP. (THE WORKMEN WILL NOTE THAT CASTING RESINS DEVELOP HEAT IMMEDIATELY AFTER BEING MIXED) DURING THE POURING PROCESS THE SHIELD AND CONDUCTORS SHOULD BE MOVED BACK AND FORTH SLIGHTLY TO AID PENETRATION OF LIQUID. WHEN FORM IS FULL ALLOW THE MIXTURE TO HARDEN ABOUT 10 MINUTES OR UNTIL IT IS FIRM AND COOL TO THE TOUCH. THEN PEEL OFF THE FORM, AND CLEAN CASTING.

E BEND CASTING BACK INTO POSITION FOR SPLICING.

DETAIL
SHOWING PENETRATION OF CASTING MIXTURE

73.220

Figure 13-23.—Preparing to splice plastic-sheathed cable to lead-sheathed cable.



STRAIGHT SPLICE

SPLICING PLASTIC INSULATED-PLASTIC SHEATHED CABLES TO PAPER INSULATED-LEAD SHEATHED CABLES

SEPARATE CONDUCTORS INTO BUNCHES BY COLOR GROUPS OR COMPLEMENTS AND SECURE IN A CONVENIENT POSITION FOR SPLICING.

BRING PAIRS TOGETHER AS NEEDED, LEAVING SUITABLE LENGTH OF SLACK FOR STAGGERED SPACING OF JOINTS THEN CUT OFF EXCESS WIRE

AS CONDUCTORS ARE SELECTED FOR SPLICING, PLASTIC SLEEVES SHALL BE PLACED.

STAGGER JOINTS FOR UNIFORM LAY

PLASTIC SLEEVE SELECTION

GAUGE OF CONDUCTOR	COLOR	INSIDE DIA.	OUTSIDE DIA.
24	GREEN	.106"	.138"
22	BLACK	.125"	.165"
19	RED	.148	.188"

REMOVE REQUIRED LENGTH OF INSULATION AS CONDUCTORS ARE SELECTED FOR SPLICING

WRAP SPLICED CONDUCTORS WITH AN ENVELOPE MADE OF POLYETHYLENE. DESICCANT SHALL BE PLACED IN ENVELOPE AS FOLLOWS:

SIZES OF CABLES	WEIGHT IN GRAMS
51 PAIR AND SMALLER	20
76 AND 101 PAIRS	40
152 AND 202 PAIRS	70
LARGER THAN 202 PAIRS	30 PER 100 PAIRS

DETAIL FOR MAKING JOINT

CUT OFF EXCESS WIRE AND SOLDER BEND PIGTAIL INTO POSITION AND SLIDE SLEEVE OVER JOINT. USE RESIN CORE SOLDER

COVER ENTIRE SPLICE WITH A SINGLE LAYER OF TAPE HALF LAPPED. DO NOT OVER LAP THE CABLE SHEATH OR METALIC SHIELD.

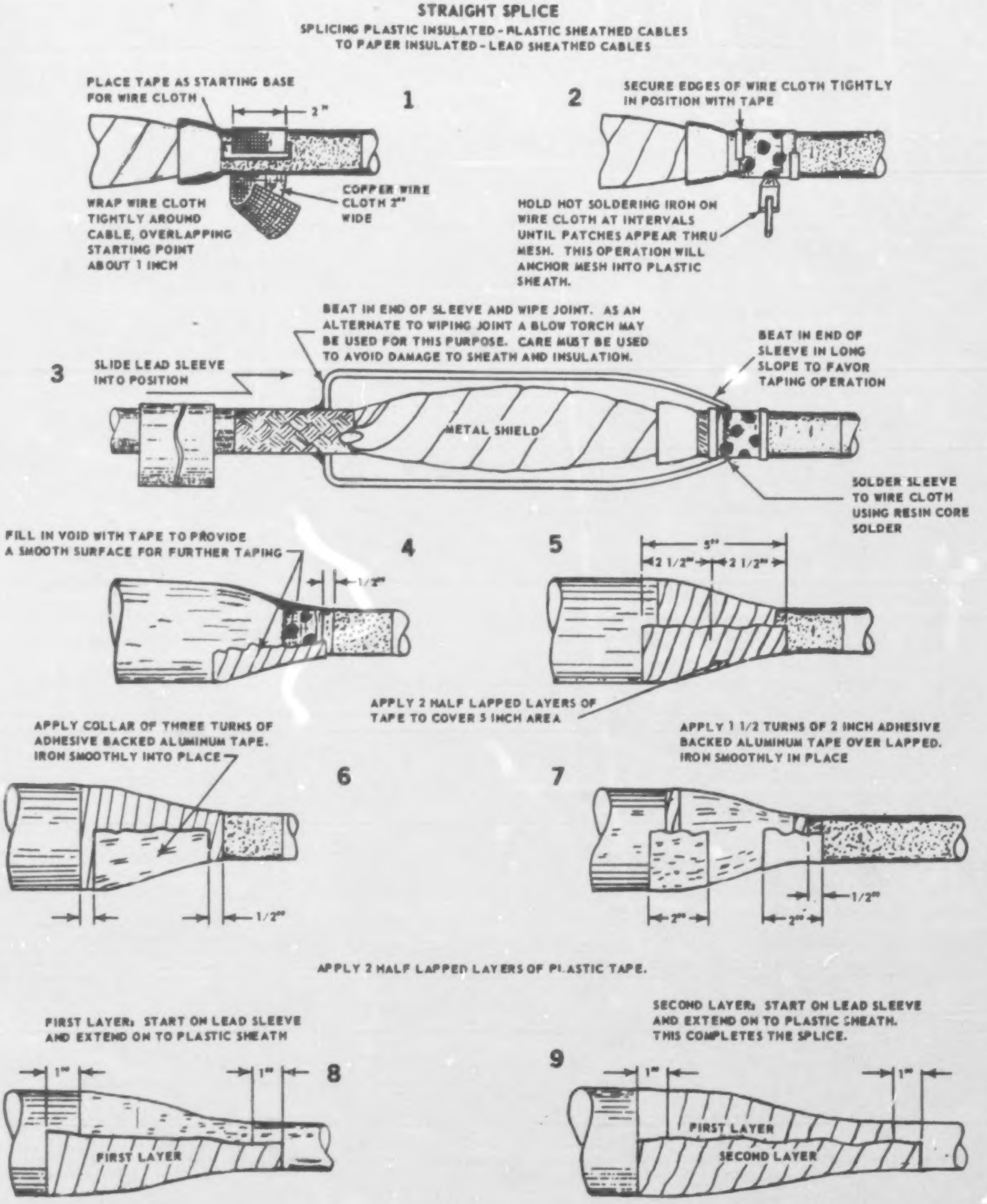
TO INSURE CONTINUITY OF SHIELD, REWRAP METAL SHIELD TAPE AND SOLDER IT TO THE LEAD SHEATH. IF SHIELD IS NOT LONG ENOUGH SOLDER ON AN ADDITIONAL PIECE OF SHIELD.

SOLDERING OPERATIONS SHALL BE PERFORMED AWAY FROM THE CABLE CORE TO PROTECT THE TAPES FROM THE HEAT OF THE SOLDERING IRON. ALLUMINUM SHIELD SHALL BE TINNED, USING ALCOA 64 ALUMINUM FLUX, 50-50 OR ROSIN CORE SOLDER SHALL BE USED IN THE SOLDERING OPERATION.

PAPER INSULATED CONDUCTORS
PLASTIC INSULATED CONDUCTORS
LEAD SLEEVE
4"
5"
SEE DETAIL FOR JOINT
PLASTIC SLEEVE
END SEAL SCUFFED SURFACED
METAL SHIELD
CLEANED SURFACE
SHIELD
SLEEVE
PLASTIC SLEEVE
PAPER INSULATED CONDUCTOR
PLASTIC INSULATED CONDUCTOR
APPX 1"
3 LOOSE HALF TURNS
5 TIGHT HALF TURNS
3/8" TO 1/2"
SHIELD
PLACE DESICCANT.
SECURE ENVELOPE IN PLACE WITH TAPE.
SLEEVE
SLEEVE

73.221

Figure 13-24.—Making the splice of plastic-sheathed cable to lead-sheathed cable.


STRAIGHT SPLICE
SPLICING PLASTIC INSULATED-PLASTIC SHEATHED CABLES TO PAPER INSULATED-LEAD SHEATHED CABLES
1
PLACE TAPE AS STARTING BASE FOR WIRE CLOTH
2"
WRAP WIRE CLOTH TIGHTLY AROUND CABLE, OVERLAPPING STARTING POINT ABOUT 1 INCH
COPPER WIRE CLOTH 2" WIDE
2
SECURE EDGES OF WIRE CLOTH TIGHTLY IN POSITION WITH TAPE
HOLD HOT SOLDERING IRON ON WIRE CLOTH AT INTERVALS UNTIL PATCHES APPEAR THRU MESH. THIS OPERATION WILL ANCHOR MESH INTO PLASTIC SHEATH.
3
SLIDE LEAD SLEEVE INTO POSITION
BEAT IN END OF SLEEVE AND WIPE JOINT. AS AN ALTERNATE TO WIPING JOINT A BLOW TORCH MAY BE USED FOR THIS PURPOSE. CARE MUST BE USED TO AVOID DAMAGE TO SHEATH AND INSULATION.
METAL SHIELD
BEAT IN END OF SLEEVE IN LONG SLOPE TO FAVOR TAPING OPERATION
SOLDER SLEEVE TO WIRE CLOTH USING RESIN CORE SOLDER
4
FILL IN VOID WITH TAPE TO PROVIDE A SMOOTH SURFACE FOR FURTHER TAPING
1/2"
5
5"
2 1/2"
2 1/2"
APPLY 2 HALF LAPPED LAYERS OF TAPE TO COVER 5 INCH AREA
6
APPLY COLLAR OF THREE TURNS OF ADHESIVE BACKED ALUMINUM TAPE. IRON SMOOTHLY INTO PLACE
1/2"
7
APPLY 1 1/2 TURNS OF 2 INCH ADHESIVE BACKED ALUMINUM TAPE OVER LAPPED. IRON SMOOTHLY IN PLACE
2"
2"
1/2"
APPLY 2 HALF LAPPED LAYERS OF PLASTIC TAPE.
8
FIRST LAYER: START ON LEAD SLEEVE AND EXTEND ON TO PLASTIC SHEATH
1"
1"
FIRST LAYER
9
SECOND LAYER: START ON LEAD SLEEVE AND EXTEND ON TO PLASTIC SHEATH. THIS COMPLETES THE SPLICE.
1"
1"
FIRST LAYER
SECOND LAYER

73.222

Figure 13-25.—Completing the splice of plastic-sheathed cable to lead-sheathed cable.

Fill in the void between the plastic sheath and the lead sleeve with vinyl tape, to provide a smooth surface for further taping. Figure 13-25 shows the taping procedure. Apply two half-lapped layers of tape, extending 2 1/2 inches on each side of the point where the lead sleeve is joined to the wire cloth (a total of 5 inches). Apply a collar of three turns of 3-inch adhesive-backed aluminum tape and iron smoothly in place with a cable dresser. This operation will allow 1/2 inch of previously placed vinyl tape to show at each end of the collar.

Apply one and a half turns of 2-inch adhesive-backed aluminum tape at each end of the collar, overlapping the previously placed aluminum tape about 1/2 inch. Iron smoothly with a cable dresser. Two-inch tape may be cut from a roll of 4-inch tape.

Apply two half-lapped layers of vinyl tape over the aluminum tape. Start the first layer on the lead sleeve 1 inch from the aluminum tape, and continue to a point on the plastic sheath 1 inch beyond the aluminum tape. Start the second layer of tape on the lead sleeve 1 inch from the end of the previous layer, and wrap to a point 1 inch beyond the end of the first layer.

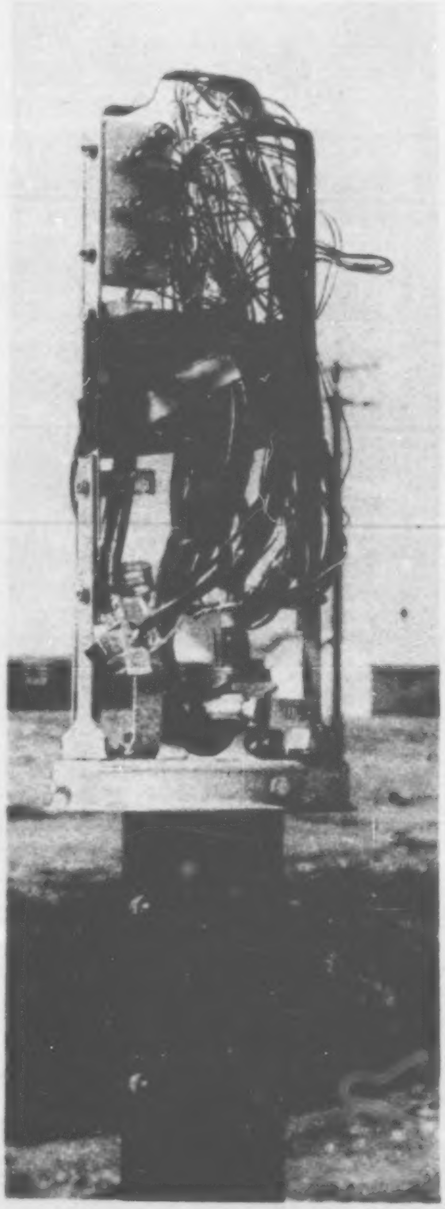
This completes the splicing operation.

SPLICING POLYETHYLENE CABLE FOR DIRECT-BURIAL INSTALLATION

Direct-burial cable is buried in a trench, usually at least 30 inches below the surface. When a splice must remain aboveground, splice or terminal housings are used. When no external housings are permitted, a casting compound and special splicing technique are used to allow the splice to remain underground.

When the cable changes from direct-burial cable to aerial cable, the housing is usually pole-mounted. However, when a terminal block to connect lines to a telephone is needed, or when a splice is to be made in the cable, a pedestal-mounted housing is used.

Figure 13-26 shows a pedestal-mounted, open-terminal housing with three pairs of conductors connected to the terminal block. In this type of housing the conductors passing through the housing (not connected to the terminal block) are not cut, but are continuous through the housing.

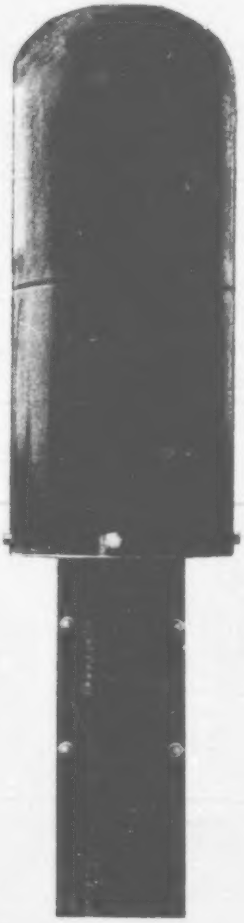


73.214

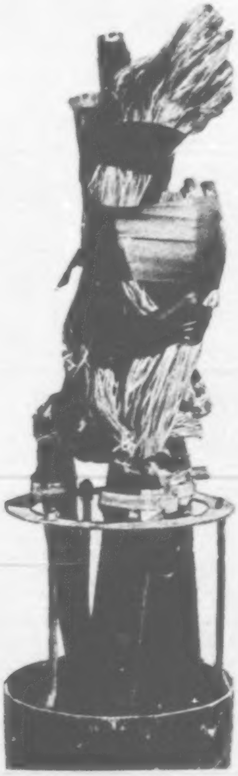
Figure 13-26.—Open-terminal housing.

Figure 13-27 shows the housing with cover in place.

An example of a splice housing is shown in figure 13-28. Figure 13-29 shows the splice housing with cover in place. Continuity of the



73.215
Figure 13-27.—Terminal housing with cover in place.



73.216
Figure 13-28.—Splice housing.

shield in direct-burial cable is accomplished by means of a bonding harness as shown in figure 13-30.

When no external housings are permitted, casting compound is used to minimize the problem of moisture. This technique is outlined in figure 13-31.

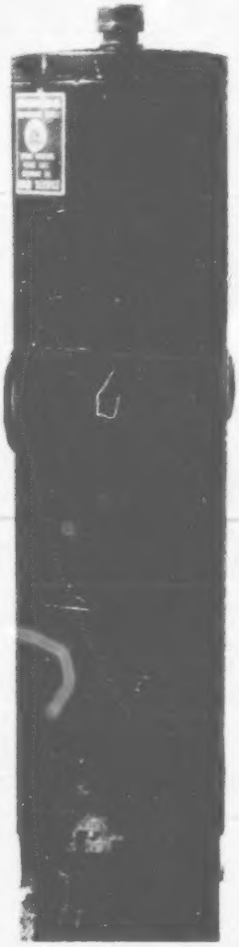
REPAIR OF LEAD-COVERED CABLE

Making minor repairs because of ring cuts, sheath breaks, lightning burns, bullet holes, or other damage to small aerial cable is part of your job. Such damage can be repaired with an acetylene torch if it does not extend through the sheath.

Water-soaked paper insulation usually causes pairs to become shorted. It follows that shorted pairs are frequently an indication that somewhere the sheath is damaged enough to allow moisture to penetrate to the insulation.

Steps in making a sheath-damage repair are as follows:

1. Opening the sheath.
2. Drying out and repair.
3. Closing the sheath.



73.217
Figure 13-29.—Splice housing with cover in place.

4. Soldering the seam, using a soldering copper or an acetylene torch.

OPENING THE SHEATH

After the fault has been located and the ladder or splicing platform has been placed for gaining access to the repair point on the cable, proceed to open the sheath as follows:

1. Straighten the cable if necessary, and reduce cable tension, also if necessary, by placing grade clamps.

2. Use a wire brush to brighten the lead sheath in the section to be split.

3. Rub stearine along the cable where the lengthwise split is to be made. As the cut is made, continue to lubricate with stearine.

4. Split the cable with a cable stripper, a cutting tool with small and large blades which can be set to cut a given depth. Adjust the small blade of the stripper so that it will penetrate 1/32 to 1/16 inch. Make the starting cuts with the small end of the blade, routing out the small lead shavings as you cut. After a definite line of cut has been established, turn the stripper over and use the large end of the blade to bevel the cut. Do not cut all the way through the sheath with the large end. Just before the blade is about to break through the sheath, reverse the tool and complete the cut with the small end.

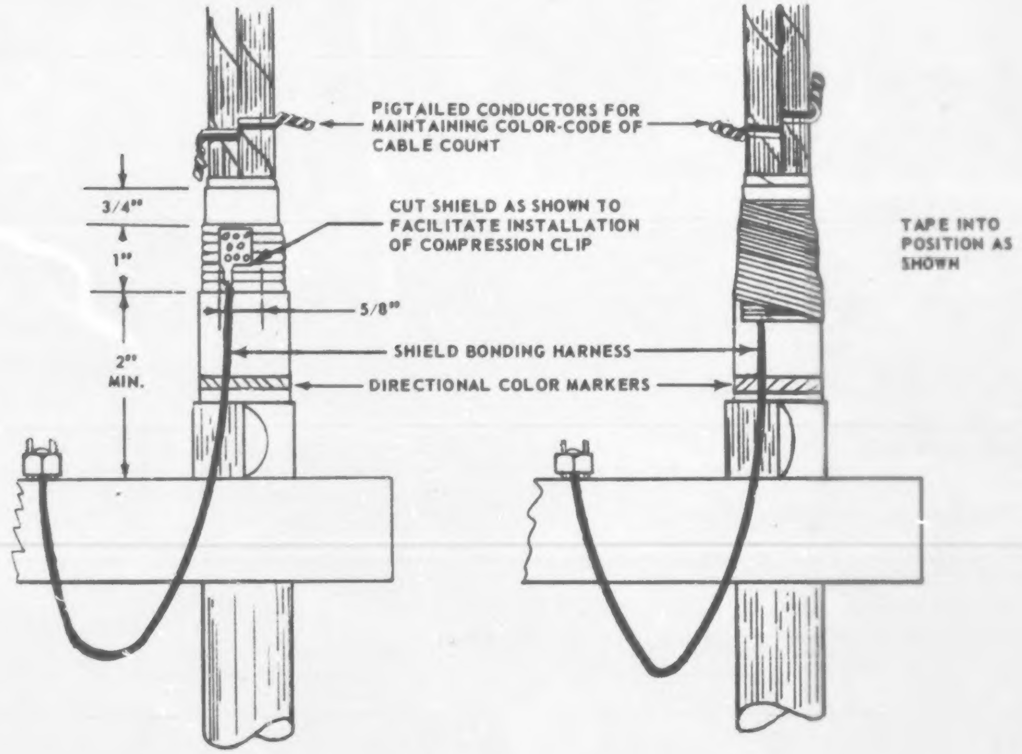
5. After you have cut through the sheath, open it with a pair of cable pliers. Grasp the handles of the cable pliers firmly and open the incision on one side. With the sharp jaw in the cut, work the pliers sideways, exerting a small downward pressure at the same time. Bend the sheath cautiously, so as not to deform it. When one side of the sheath is bent back, repeat the process on the other side.

When the sheath has been opened, push out the cable by inserting wooden wedges between sheath and cable as shown in figure 13-32.

DRYING OUT AND REPAIR

If wires must be spliced, the cut must be long enough so that splices can be properly staggered. Apply paper tape to any points at which the wire is sound but the insulation has become blackened because of electrolytic action. To apply the tape, pull the pair out and cut a piece of tape long enough to extend at least 1/2 inch beyond the corroded portion. Press it down with your fingers, and trim off the excess. In hot weather take great care that perspiration from your hands does not dampen the insulation. If the conductor insulation is damp or wet, a procedure similar to that described in figure 13-24 may be used, but the envelope and desiccant must be removed to close the sheath as described in the following steps.

After all damaged wires are repaired, push cotton tape under the edges of the sheath with a


PIGTAILED CONDUCTORS FOR MAINTAINING COLOR-CODE OF CABLE COUNT
3/4"
1"
2" MIN.
CUT SHIELD AS SHOWN TO FACILITATE INSTALLATION OF COMPRESSION CLIP
TAPE INTO POSITION AS SHOWN
5/8"
SHIELD BONDING HARNESS
DIRECTIONAL COLOR MARKERS

STEPS

1. REMOVE OUTER JACKET, TRIM CABLE SHIELD AND INNER JACKET AS ILLUSTRATED.
2. FOLD BACK OVERLAPPED EDGE OF SHIELD AND COMPRESS CLIP OF SHIELD BONDING HARNESS TO SHIELD AS SHOWN USING SPECIAL COMPRESSING TOOL.
3. APPLY VINYL TAPE OVER SHIELD AND BONDING HARNESS AS ILLUSTRATED. TAPE SHOULD BE APPLIED AS NEEDED TO PREVENT CONTACT BETWEEN SHIELD AND METAL OF TERMINAL HOUSING.
4. SECURE END OF SHIELD BONDING HARNESS IN SPLIT-BOLT GROUNDING CONNECTOR.

73.218

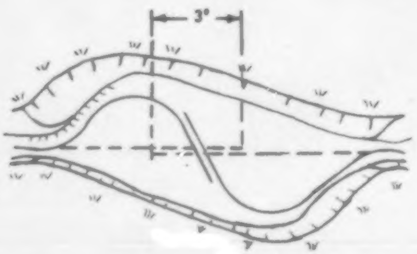
Figure 13-30.—Installation of bonding harness.

butting tool. Wrap the core with 1-inch tape which has been boiled out in paraffin, and then push the core back into the sheath. Test the cable pairs to ensure that all trouble is cleared.

CLOSING THE SHEATH

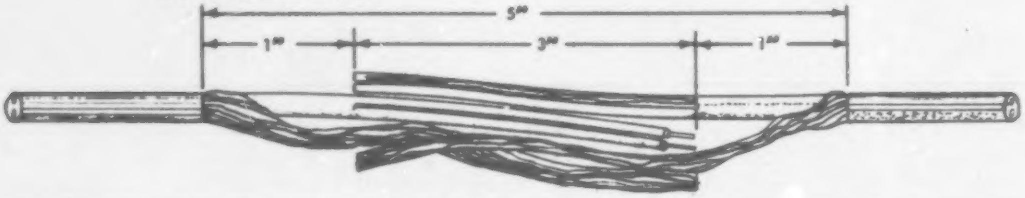
Before closing the cut in the sheath, cut a piece of pressboard about 5/16 inch wide and as long as the length of the opening. Lubricate with stearine generously, so that the edges of the sheath will close readily around the pressboard strip; after removing the wedges and pushing the cable back into the sheath, place the strip under the opening. It is not necessary to close the cut completely, but if it is left partly open, the strip of pressboard should cover the cable so that it will not be damaged during the process of sealing up the split in the sheath.

In closing the sheath you should bend it into shape gradually. First press it together

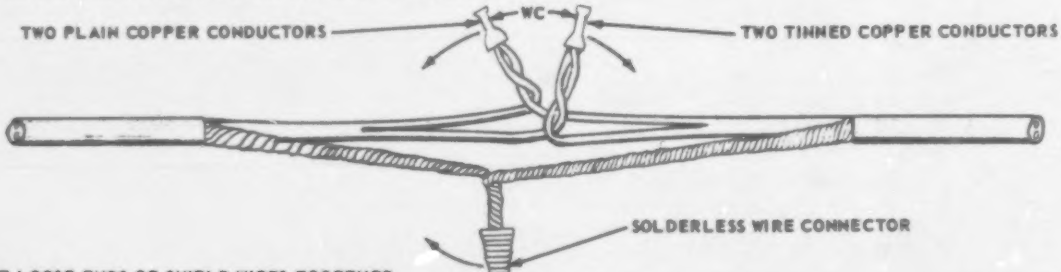


NOTE:

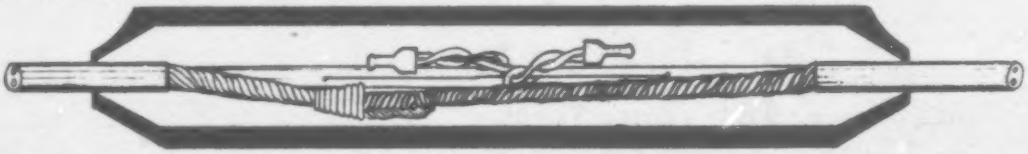
EXCAVATE A TRENCH AS SHOWN, PROVIDE A MINIMUM OF THREE FEET OVERLAP IN THE BURIED WIRE AND PROCEED TO MAKE THE DIRECT BURIAL WIRE SPLICE AS SHOWN IN THE FOLLOWING STEPS:



1. REMOVE APPROXIMATELY 4" OF JACKET FROM ENDS AS SHOWN. CLEAN FLOODING COMPOUND FROM SHIELD WIRES AND CONDUCTOR INSULATION.
2. SLIT INSULATION APPROXIMATELY 3" AND SEPARATE CONDUCTORS.
3. REMOVE APPROXIMATELY 1/4" OF INSULATION FROM CONDUCTORS, INSERT INTO INSULATED WIRE CONNECTORS, CRIMP AND BEND INTO POSITION AS SHOWN.


TWO PLAIN COPPER CONDUCTORS
WC
TWO TINNED COPPER CONDUCTORS
SOLDERLESS WIRE CONNECTOR

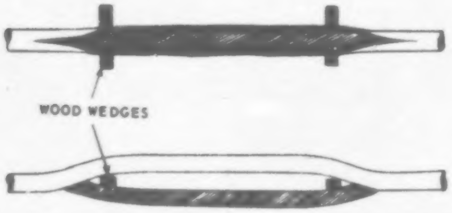
4. TWIST LOOSE ENDS OF SHIELD WIRES TOGETHER.
5. BRING SHIELD WIRES TOGETHER, MAKE PIGTAIL, INSERT ENDS INTO SOLDERLESS WIRE CONNECTOR AND TWIST INTO POSITION.
6. BRING SHIELDS AND CONDUCTOR SPLICES INTO ALIGNMENT AND APPLY TAPE AS REQUIRED TO OBTAIN COMPACT BUNDLE FOR POSITIONING IN MOLD.



7. POSITION MOLD AROUND SPLICE BUNDLE AND APPLY TAPE AT EACH END TO PREVENT COMPOUND MIXTURE FROM LEAKING.
8. SET MOLD IN LEVEL POSITION, PREPARE CASTING COMPOUND AS RECOMMENDED BY MANUFACTURER AND POUR.
9. DO NOT DISTURB SPLICE OR REFILL TRENCH UNTIL CASTING COMPOUND HAS COMPLETELY CURED.

73.219

Figure 13-31.—Splicing polyethylene cable for direct-burial installation.



73.203
Figure 13-32.—Wedging section of cable out of opened sheath.

with your hands, then shape it into its original shape by applying pressure with tongs kept lubricated with stearine. Do not roll the tongs over the sheath, because this will create depressions around the circumference. Take care, also, not to apply pressure directly over the cut until the cable is well shaped, or you may flatten the cable.

SOLDERING THE SEAM

After the sheath has been closed over the cable so that the edges of the cut are from 1/8 to 1/4 inch apart, use the scoring tool and a wire brush to clean the sheath thoroughly. Apply pasters along the edges and ends of the cut, to fix the width and length of the closing seam. Set the pasters about 1/16 to 1/8 inch away from the edges of the cut. Use a half-round bastard file at each end of the cut to form a depression into which solder can be flowed to seal any fine cracks caused by bending back the sheath. After the pasters are set, apply stearine to the portion to be soldered.

Using a Soldering Copper

Fuse stearine core solder to the cut by holding the end of the solder bar in contact with the sheath. Hold the handle of the soldering copper in one hand at a 45° angle to the cable. Rest one beveled edge of the copper on the paper paster at one end of the sheath opening. Move the iron onto the sheath along the opening while feeding bar solder (held in the other hand) to the vertical beveled edge of the copper ahead of the iron. The copper must be kept moving at a speed just slow enough to fill the opening with the solder and fuse it to the sheath.

Part of the copper edge resting on the sheath must also rest on the paper paster along one side of the opening to make a smooth continuous seam. There will be a slight buildup as the molten solder streams out from behind the copper. It may be necessary to pass the copper along the other paster to dress up the seam. After completing the soldering operations, remove the pasters.

Using an Acetylene Torch

Small sheath defects, such as ring cuts and cracks, can be repaired by acetylene torch. Acetylene, however, is a highly flammable gas which is explosive in confined spaces. Consequently, never use the acetylene torch for making repairs in a manhole or other enclosed space. Before you use an acetylene torch, be sure you fully understand its operation and particularly, the safety precautions that go with it.

To make sheath repairs with an acetylene torch, you again use stearine core solder. Thoroughly clean the area around the defect with a brushing motion. Apply the torch flame to the cleaned area, being careful not to concentrate long on one spot. Apply solder over the area of the defect, using sufficient heat to tin thoroughly. Build up enough solder to fill the crack or depression. Use a small finishing cloth to pack the solder into the defect, and to smooth off the patch so that is is only slightly more than flush with the surface of the sheath. A repair should extend from 1/4 to 1/2 inch beyond the defect.

Never keep the torch lighted except when making repairs. If spots to be repaired are close together, you may move from one to the other without extinguishing the torch, if you don't have to change position radically. However, if you have to change position or pass a hole, turn off the torch, and relight again in the new position.

CHAPTER 14

ADMINISTRATION

As a CE3 or 2, you still have a great deal to learn about your trade, including the development of skills required in performing tasks concerning electrical generating and distribution systems and service. And from time to time you will be called upon to fill the role of supervisor. Your duties and responsibilities as a supervisor will be limited, but they will gradually increase as you advance from one pay grade to the next. This chapter discusses one of the major responsibilities of a supervisor—administration. It is not intended to tell you all you need to know about the subject, but to give you some idea of what you, as a CE3 or CE2, can expect in the way of administrative duties. As part of this chapter, information also is included on the purpose of the Personnel Readiness Capability Program (PRCP).

ASSIGNMENT AS CREW LEADER

As you gain experience in construction work, you will probably be called upon to serve as crew leader of CE teams (or crews) consisting of 3 to 5 men. These teams perform various types of work. For example, a three-man team (two linemen and one groundman) may be assigned the job of mounting crossarms and racks on poles. The groundman readies all bolts, washers, nuts, braces, and crossarms to be used. The groundman attaches the handline to the crossarm in the prescribed manner for the lineman to pull into a working position. After the lineman inserts a through-bolt, he casts off the upper half-hitch, and the groundman then heaves the crossarm level. The lineman fastens the braces to the crossarm in a secure manner. When double crossarms are used, they are fastened together at the ends with double-arm bolts allowing for the lineman to adjust the spacing between them. As the supervisor in charge of a job like the one described, you would be in charge of all operations, and be responsible for the care and maintenance of the equipment.

Your duties as a crew leader will vary from one activity to another. At most activities, however, a crew leader's duties may involve planning work assignments, supervising work teams, initiating requisitions, and keeping time cards. Information that will aid you in carrying out these duties is given below.

PLANNING WORK ASSIGNMENTS

For purposes of this discussion, planning is the process of determining requirements and devising and developing methods and schemes of action for construction of a project. Proper planning saves time and money for the Navy and makes the job easier for all concerned. The following pointers will aid you in planning day-to-day work assignments for work teams.

When you are assigned a job, whether in writing or orally, one of the first things to do is to make sure you understand clearly just what is to be done. Study plans and specifications where applicable. If you have any questions, find out the answers from those in a position to supply the information you need. Among other things, make sure you understand the priority of the project, time of completion, and any special instructions to be followed.

In planning for a small or large project, you must consider the capability of the men available for assignment. Determine who is to do what and how long it should take to complete the job. Realizing that idleness may breed discontent, arrange to have another job ready for starting as soon as the first one is finished.

Establish goals for each work day and encourage your men to work together as a team in accomplishing these goals. You want your goals to be such that your men will be kept busy, but make sure they are realistic. During an emergency, most men will make a tremendous effort to meet the deadline. But men are not machines, and when there is no emergency, they cannot be expected to continuously achieve an excessively high rate of production. In your planning, you must also allow for things which are not considered as direct labor, such as safety training, disaster control training, leave, and liberty.

To help ensure that the job is done properly and on time, you will want to consider the method to use in accomplishing the job. If there is more than one way of doing a particular job, make sure the method you select is the best way. After selecting a method, analyze it to see if it could be simplified with a resultant savings in time and effort.

Plan material requirements so that you will not have a log of materials left over. But don't have your material estimate so low that you may run out of necessary items and delay the job so that your men may remain idle, until more materials can be obtained. At times, circumstances come about that make it necessary to use more materials than anticipated.

Consider the tools and equipment you will need for the job and arrange to have them available at the place where the work is to be done, and at the time the work is to get underway. Determine who will use the tools, and make sure the men to whom they are assigned know how to use them properly and safely. Plan to have the materials so that they will be in an accessible place but not pose a safety hazard.

SUPERVISING WORK TEAMS

After a job has been properly planned, it is necessary to supervise the job carefully to ensure that it is completed properly and on time. Some pointers that will aid you in supervising work teams are given below.

Prior to starting a job, make sure your men know what is to be done. Give instructions clearly, and urge your men to ask questions on any points that are not clear to them. Be sure the men know all pertinent safety precautions and wear safety apparel where required.

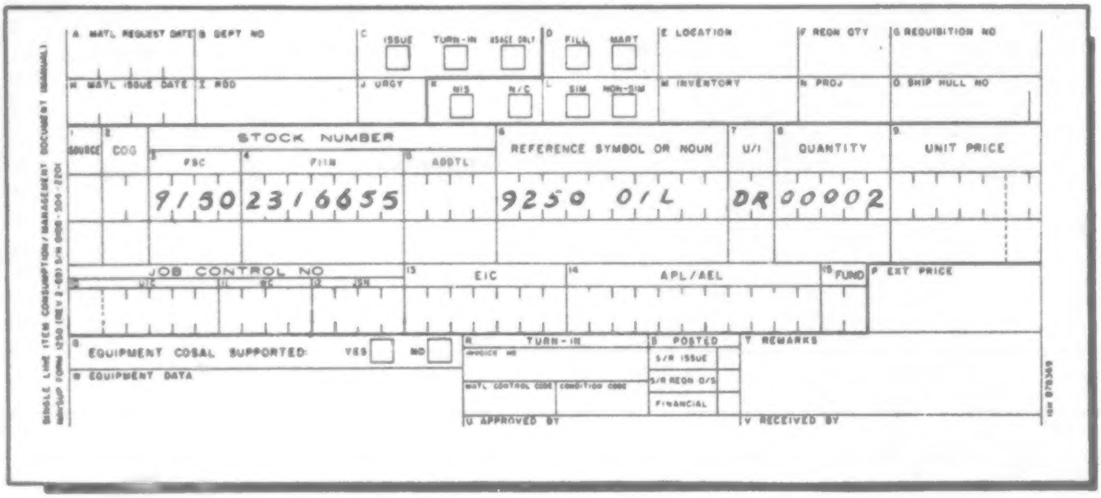
While the job is underway, check from time to time to ensure that the work is progressing satisfactorily. Determine if the proper methods, materials, tools and equipment are being used. If a man is doing a job wrong, stop him and point out what he is doing wrong. Then explain the correct procedure and check to see that he follows it. In checking the work of your men, try to do it in such a way that your men will feel that the purpose of your inspection is to teach, guide and direct, rather than to criticize and find fault.

The supervisor should make sure that his men observe all applicable safety precautions. He should also watch for hazardous conditions, improper use of tools and equipment, and unsafe work practices which could cause accidents and possibly result in injury to personnel. Many young men are heedless of danger, or think a particular regulation is unnecessary. Very often such persons get hurt.

When time permits, rotate the men on various jobs. Rotation gives them varied experience and will help ensure your having men who can do the work if someone is hospitalized, transferred, or goes on leave.

A good supervisor should be able to get others to work together in getting the job accomplished. He should maintain an approachable attitude towards his men, making them feel free to come and seek his advice when in doubt as to any phase of the project. Emotional balance is especially important; a supervisor cannot become panicky before his men, unsure of himself in the face of conflicting forces, or pliable with influence. He should use tact and courtesy in dealing with his men and not show partiality to certain members of the work team. He should keep his men informed on matters that affect them personally or concern their work. He should also seek to maintain a high level of morale, keeping in mind that low morale can have a definite effect upon the quantity and quality of work turned out by his men.

The above is only a brief treatment on the subject of supervision. As you advance in rate you will be spending more and more of your time in supervising others, so let us urge that you make a continuing effort to learn more about the subject. Study books on supervision as well as leadership. Also, read articles on topics of concern to supervisors—such as safety, training, job planning, etc.—that appear from time to time in trade journals and other publications. There is a big need in the Navy for petty officers who are skilled supervisors. So, consider the role as supervisor a big challenge and endeavor to become proficient in all areas of the supervisor's job.



SINGLE LINE ITEM CONSUMPTION/MANAGEMENT DOCUMENT (MANUAL)

A MATL REQUEST DATE | B DEPT NO | C ISSUE ☐ TURN-IN ☐ USAGE ONLY ☐ | D FILL ☐ MART ☐ | E LOCATION | F REQN QTY | G REQUISITION NO

H MATL ISSUE DATE | I RDD | J URGY | K NIS ☐ N/C ☐ | L SIM ☐ NON-SIM ☐ | M INVENTORY | N PROJ | O SHIP HULL NO

1 SOURCE	2 COG	STOCK NUMBER 3 FSC	4 FIIN	5 ADDTL	6 REFERENCE SYMBOL OR NOUN	7 U/I	8 QUANTITY	9 UNIT PRICE
		9150	2316655		9250 OIL	DR	00002	

JOB CONTROL NO | 13 EIC | 14 APL/AEL | 15 FUND | P EXT PRICE

Q EQUIPMENT COSAL SUPPORTED: YES ☐ NO ☐

Q EQUIPMENT DATA

R TURN-IN INVOICE NO | MATL CONTROL CODE | CONDITION CODE

S POSTED: S/R ISSUE | S/R REQN O/S | FINANCIAL

T REMARKS

U APPROVED BY

V RECEIVED BY

17.84

Figure 14-1.—Single Line Item Consumption/Management Document (Manual); NAVSUP Form 1250.

PREPARING REQUISITIONS

As a crew leader, you must be able to prepare requisitions, which are orders from one activity requesting material or service from another activity. The most common method of requisitioning involves the use of printed forms which are designed to provide all necessary information for physical transfer of the material and accounting requirements.

Two forms used for requisitioning materials are the Single Line Item Consumption/Management Document (Manual), NAVSUP Form 1250 (fig. 14-1) and the Requisition and Invoice/Shipping Document, DD Form 1149 (fig. 14-2).

As a crew leader, you are not usually required to make up the entire NAVSUP Form 1250; however, you must list the item's stock number (when available), quantity, and reference symbol or name of each item needed. This form (NAVSUP Form 1250) is turned in to the expediter who will check it over, completing the other information, sign and then forward it to the Material Liaison Officer (MLO) or Supply Department for processing.

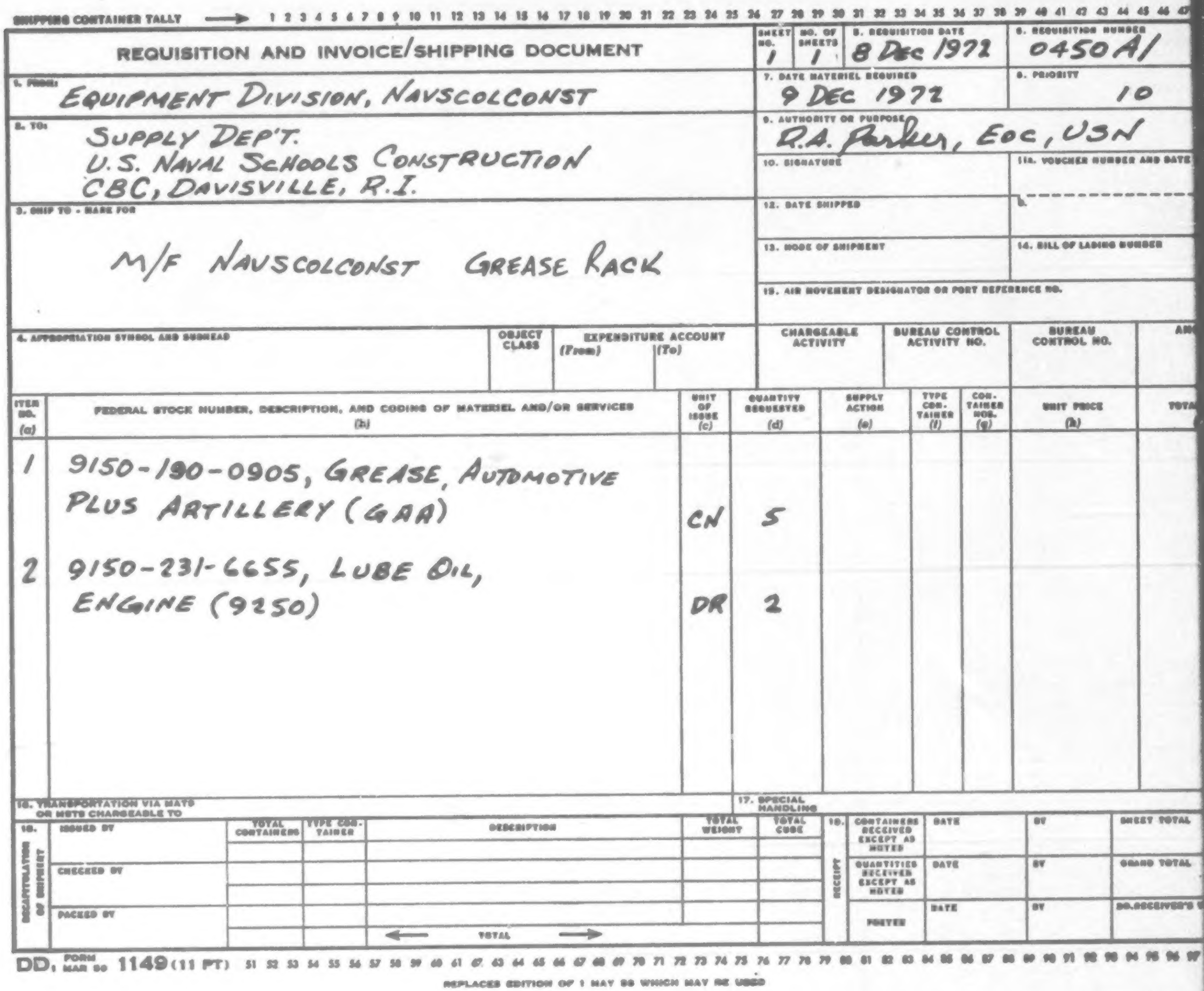
You are not likely to use DD Form 1149 very often. The items most frequently ordered on DD Form 1149 are bulk fuels and lubricants. This form is limited to a single page and must contain no more than nine line items. DD Form 1149 has many uses. It is not necessary to fill in all the blocks when this form is used as a requisition.

In requisitioning material you will need to know about the Federal Supply Classification (FSC) system. Information on the FSC system and other topics relating to supply is given in Military Requirements for Petty Officer 3 & 2, NAVPERS 10056-C.

TIMEKEEPING

Your duties may involve the posting of entries on time cards for both military and civilian personnel. Therefore, you should know the types of information called for on time cards and understand the importance of accuracy in labor reporting. Here, we are primarily interested in the labor reporting system used in the battalion. You will find, however, that the system employed at shore-based activities is similar to that used in the battalion.

In order to record and measure the number of man-hours the unit spends on various functions, a labor accounting system is mandatory. This system must permit the day-by-day accumulation of labor utilization data in sufficient detail and in a manner that allows ready compilation of information required by the Operations Officer



SHIPPING CONTAINER TALLY ⟶ 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47

REQUISITION AND INVOICE/SHIPPING DOCUMENT

SHEET NO. 1

NO. OF SHEETS 1

5. REQUISITION DATE 8 Dec 1972

6. REQUISITION NUMBER 0450A1

1. FROM: EQUIPMENT DIVISION, NAVSCOLCONST

7. DATE MATERIEL REQUIRED 9 DEC 1972

8. PRIORITY 10

2. TO: SUPPLY DEP'T.
U.S. NAVAL SCHOOLS CONSTRUCTION
CBC, DAVISVILLE, R.I.

9. AUTHORITY OR PURPOSE R.A. Parker, EOC, USN

10. SIGNATURE

11a. VOUCHER NUMBER AND DATE

b.

12. DATE SHIPPED

3. SHIP TO - MARK FOR M/F NAVSCOLCONST GREASE RACK

13. MODE OF SHIPMENT

14. BILL OF LADING NUMBER

15. AIR MOVEMENT DESIGNATOR OR PORT REFERENCE NO.

4. APPROPRIATION SYMBOL AND SUBHEAD

OBJECT CLASS

EXPENDITURE ACCOUNT (From) (To)

CHARGEABLE ACTIVITY

BUREAU CONTROL ACTIVITY NO.

BUREAU CONTROL NO.

ITEM NO. (a)	FEDERAL STOCK NUMBER, DESCRIPTION, AND CODING OF MATERIEL AND/OR SERVICES (b)	UNIT OF ISSUE (c)	QUANTITY REQUESTED (d)	SUPPLY ACTION (e)	TYPE CON-TAINER (f)	CON-TAINER NOS. (g)	UNIT PRICE (h)	TOTA
1	9150-190-0905, GREASE, AUTOMOTIVE PLUS ARTILLERY (GAA)	CN	5					
2	9150-231-6655, LUBE OIL, ENGINE (9250)	DR	2					

16. TRANSPORTATION VIA MATS OR MSTS CHARGEABLE TO

17. SPECIAL HANDLING

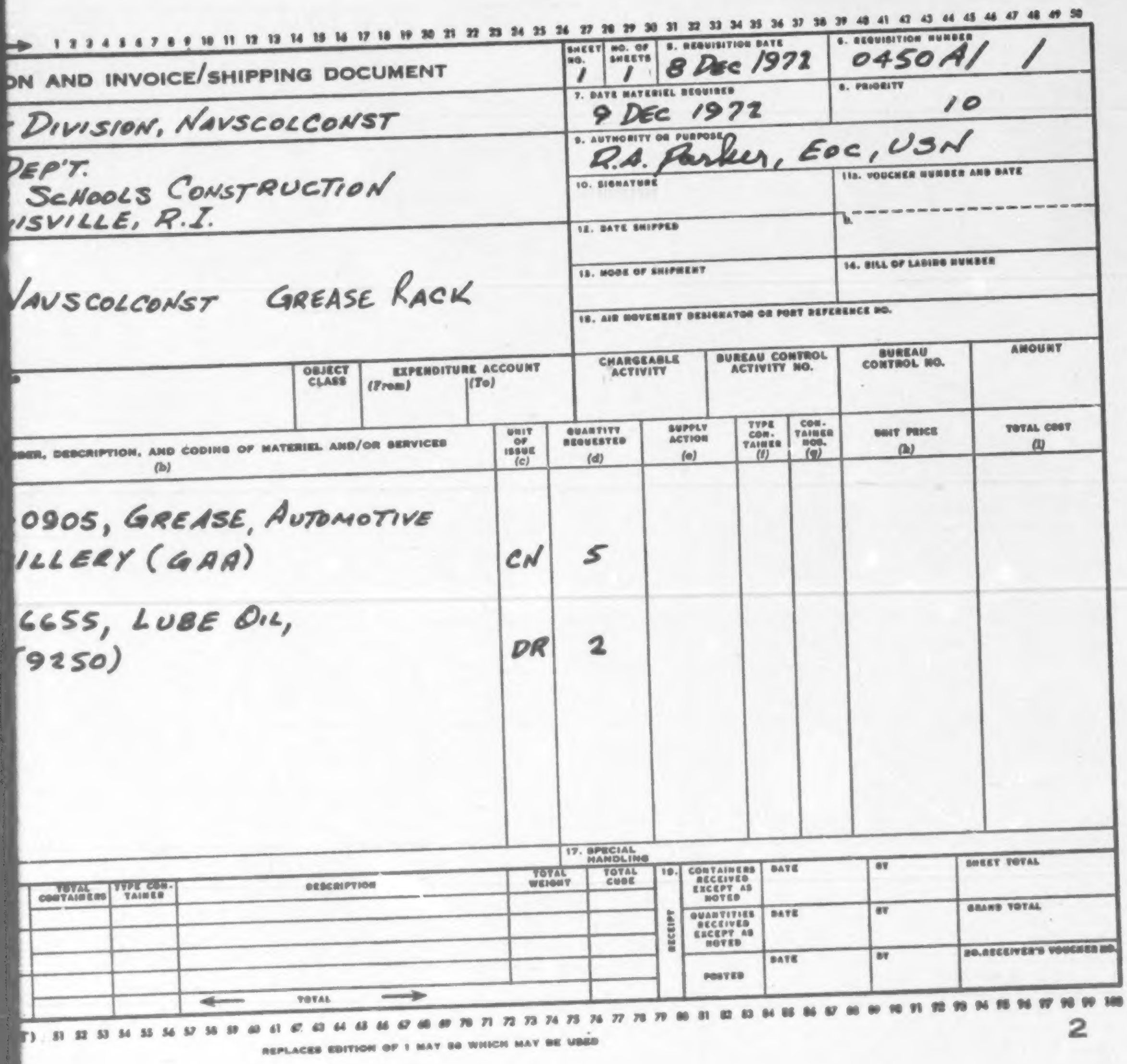
18. RECAPITULATION OF SHIPMENT		TOTAL CONTAINERS	TYPE CON-TAINER	DESCRIPTION	TOTAL WEIGHT	TOTAL CUBE
	ISSUED BY					
	CHECKED BY					
	PACKED BY			← TOTAL →		

19. RECEIPT				
	CONTAINERS RECEIVED EXCEPT AS NOTED	DATE	BY	SHEET TOTAL
	QUANTITIES RECEIVED EXCEPT AS NOTED	DATE	BY	GRAND TOTAL
	POSTED	DATE	BY	DD.RECEIVER'S

DD FORM MAR 60 1149 (11 PT) 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97

REPLACES EDITION OF 1 MAY 58 WHICH MAY BE USED

Figure 14-2.—Requisition and Invoice/Shipping Document, DD Form 1149.



ON AND INVOICE/SHIPPING DOCUMENT

SHEET NO. 1

NO. OF SHEETS 1

5. REQUISITION DATE 8 Dec 1972

6. REQUISITION NUMBER 0450A1 1

7. DATE MATERIEL REQUIRED 9 DEC 1972

8. PRIORITY 10

DIVISION, NAVSCOLCONST

DEP'T.
SCHOOLS CONSTRUCTION
ISVILLE, R.I.

9. AUTHORITY OR PURPOSE R.A. Parker, EOC, USN

10. SIGNATURE

11a. VOUCHER NUMBER AND DATE

b.

12. DATE SHIPPED

13. MODE OF SHIPMENT

14. BILL OF LADING NUMBER

15. AIR MOVEMENT DESIGNATOR OR PORT REFERENCE NO.

NAVSCOLCONST GREASE RACK

	OBJECT CLASS	EXPENDITURE ACCOUNT (From)	(To)	CHARGEABLE ACTIVITY	BUREAU CONTROL ACTIVITY NO.	BUREAU CONTROL NO.	AMOUNT

BER, DESCRIPTION, AND CODING OF MATERIEL AND/OR SERVICES (b)	UNIT OF ISSUE (c)	QUANTITY REQUESTED (d)	SUPPLY ACTION (e)	TYPE CON-TAINER (f)	CON-TAINER NOS. (g)	UNIT PRICE (h)	TOTAL COST (i)
0905, GREASE, AUTOMOTIVE ILLERY (GAA)	CN	5					
6655, LUBE OIL, (9250)	DR	2					

17. SPECIAL HANDLING

TOTAL CONTAINERS	TYPE CON-TAINER	DESCRIPTION	TOTAL WEIGHT	TOTAL CUBE
		← TOTAL →		

19. RECEIPT		DATE	BY	
	CONTAINERS RECEIVED EXCEPT AS NOTED	DATE	BY	SHEET TOTAL
	QUANTITIES RECEIVED EXCEPT AS NOTED	DATE	BY	GRAND TOTAL
	POSTED	DATE	BY	20. RECEIVER'S VOUCHER NO.

REPLACES EDITION OF 1 MAY 58 WHICH MAY BE USED

2

43.3

Figure 14-2.—Requisition and Invoice/Shipping Document, DD Form 1149.

in the management of the manpower resources. It also aids in the preparation of the various reports to higher authority.

While the system may vary slightly from one unit to another, they are so similar that the one described in this manual can be considered as being typical for all units.

The unit must account for all labor expended in carrying out assigned tasks and functions. This accounting must include the work performed by the reporting unit and, when applicable, work performed by civilian labor and the military personnel of other activities. Labor expenditures must be accumulated under a number of reporting categories. This degree of reporting detail is required to provide the management data necessary to determine labor expenditures on project work for calculation of statistical labor costs, and comparison of actual construction performance with estimating standards. It also serves to determine the effectiveness of labor utilization in performing administrative and support functions, both for internal unit management and for development of planning standards by higher command.

For timekeeping and labor reporting purposes, total labor is considered as being either in one of two categories, i.e., productive or overhead. PRODUCTIVE LABOR includes all labor that directly or indirectly contributes to accomplishment of the unit's mission, including construction operations, military operations, and training. Productive labor is accounted for in two categories: direct and indirect labor.

1. DIRECT LABOR includes all labor expended directly on assigned construction tasks, either in the field, or in the shop, and that which contributes directly to the completion of the end product. Direct labor must be reported separately for each assigned construction item.

2. INDIRECT LABOR comprises labor required to support construction operations, but which does not produce an end product itself.

OVERHEAD LABOR is not considered to be productive labor in that it does not contribute directly or indirectly to the end product. It includes all labor that must be performed regardless of the assigned mission.

During the planning and scheduling of a construction project, each phase of the project considered as direct labor is given an identifying code, usually by the Operations Department. For example, "clearing and grubbing of site" may be assigned code R-15, "trenching" R-16, and "pipe laying" R-17. Due to the many types of construction projects encountered and different operations involved, codes for direct labor reporting may vary widely from one activity to another. The crew leader uses direct labor codes in reporting the hours spent by each member of his crew during each work day on assigned construction tasks.

Codes also are used to report time spent by crew members in the following categories: indirect labor, military operations and readiness, disaster control operations, training, and overhead labor. You will find the codes shown in figure 14-3 used at most activities to indicate time spent in these categories.

The crew leader's report is submitted on a daily labor distribution report form such as that shown in figure 14-4. The report is prepared by the crew leader for each phase of the construction project that his crew is involved with, and immediately provides a breakdown by man-hours of the activities in the various labor codes for each man in the crew for any given day on any given project. It should be reviewed at the company level by the Platoon Commander, the Assistant Company Commander, and the Company Commander, and should be initialed by the Company Commander before it is forwarded to the Operations Department. It will be tabulated by the Management Division of the Operations Department, along with all of the daily labor distribution reports received from each company and department in the unit. It serves as the means by which the Operations Officer analyzes the labor distribution of his total manpower resources for any given day, and as feeder information for the preparation of the monthly operations report, and any other resource reports required of the unit.

Bear in mind that this information must be accurate and timely, and that each level in the company organization should review it for an analysis of its own internal construction management and performance, rather than having it serve merely as a feeder report to the Operations Officer.

PRODUCTIVE LABOR. Productive labor includes all labor that directly contributes to the accomplishment of the Naval Mobile Construction Battalion, including construction operations and readiness, disaster recovery operations, and training.

DIRECT LABOR. This category includes all labor expended directly on assigned construction tasks, either in the field or in the shop, and which contributes directly to the completion of the end product.

INDIRECT LABOR. This category comprises labor required to support construction operations, but which does not produce in itself. Indirect labor reporting codes are as follows:

X01 Construction Equipment Maintenance, Repair and Records
X02 Operation and Engineering
X03 Project Supervision
X04 Project Expediting (Shop Planners)
X05 Location Moving
X06 Project Material Support
X07 Tool and Spare Parts Issue
X08 Other

MILITARY OPERATIONS AND READINESS. This category comprises all manpower expended in actual military operations, unit embarkation, and planning and preparations necessary to insure unit military and mobility readiness. Reporting codes are as follows:

M01 Military Operations
M02 Military Security
M03 Embarkation
M04 Unit Movement
M05 Mobility Preparation
M06 Contingency
M07 Military Administrative Functions
M08 Mobility & Defense Exercise
M09 Other

DISASTER CONTROL OPERATIONS

D01 Disaster Control Operations
D02 Disaster Control Exercise

TRAINING. This category includes attendance at service schools, factory and industrial training courses, fleet type training, and short courses, military training, and organized training conducted within the battalion. Reporting codes are as follows:

T01 Technical Training
T02 Military Training
T03 Disaster Control Training
T04 Leadership Training
T05 Safety Training
T06 Training Administration

OVERHEAD LABOR. This category includes labor which must be performed regardless of whether a mission is assigned, and which does not contribute to the assigned mission. Reporting codes are as follows:

Y01 Administrative & Personnel
Y02 Medical & Dental Department
Y03 Navy Exchange and Special Services
Y04 Supply & Disbursing
Y05 Commissary
Y06 Camp Upkeep & Repair
Y07 Security
Y08 Leave & Liberty
Y09 Sickcall, Dental & Hospitalization
Y10 Personal Affairs
Y11 Lost Time
Y12 TAD not for unit
Y13 Other

133.417(54F)

Figure 14-3.—Subcategories of labor.

THE PERSONNEL READINESS CAPABILITY PROGRAM

The Personnel Readiness Capability Program (PRCP) provides a standard means of identifying, collecting, processing, and utilizing information on all members of the Naval Construction Force, both active and reserve. This information can be used by all levels of management and supervision to determine a unit's readiness capability by comparing it to actual or planned requirements.

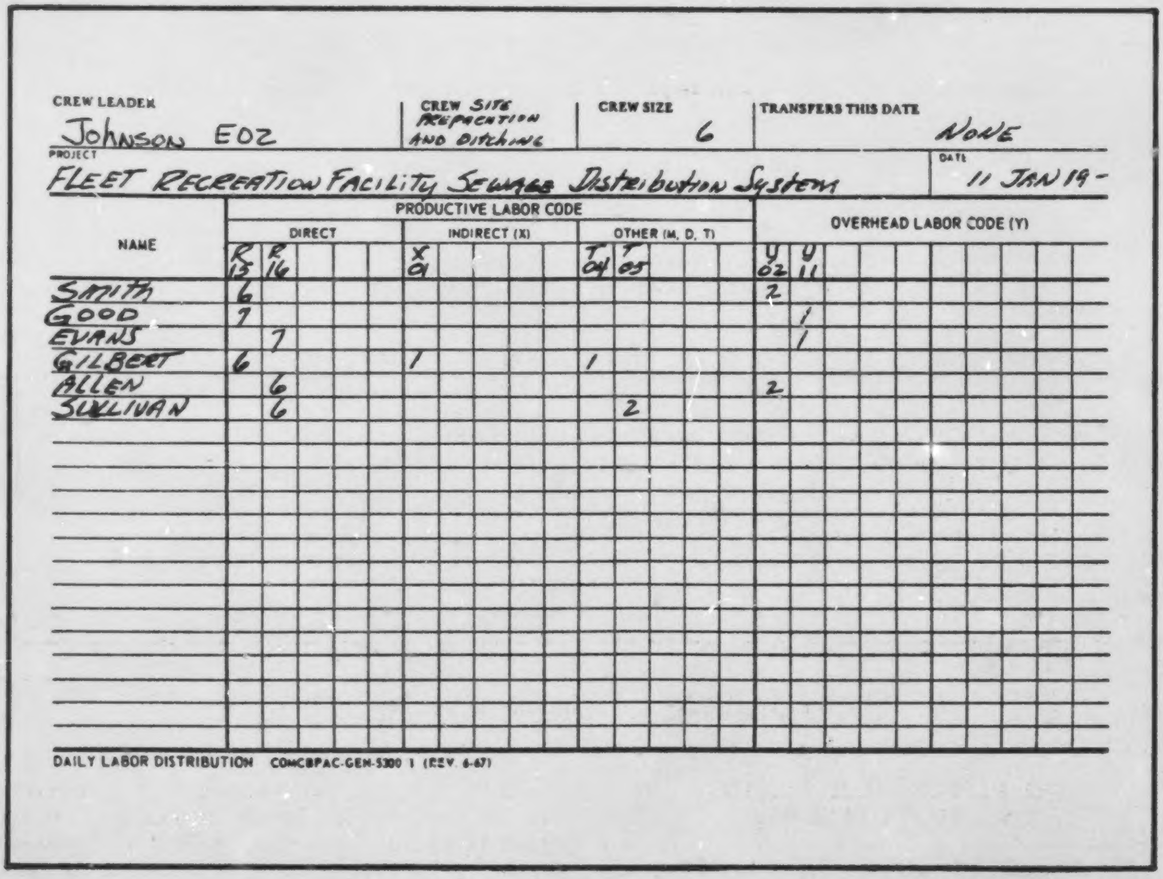
The majority of PRCP information consists of an inventory of individual skills acquired through formal or on-the-job training. A record of these skills, combined with other data from the service record, such as expiration of enlistment, rotation data, and so on, provides a ready means of predicting future capabilities and requirements. Some of these may be:

1. Construction and military capabilities.
2. Personnel, logistics, and training requirements.
3. Berthing, messing, and housing requirements.
4. Contingency requirements.

The most important aspects of the Personnel Readiness Capability Program, at your level, are collecting and passing along skill information on yourself and your men. However, the initial PRCP skill inventory will be based upon an interview with your crew/squad leader or another senior petty officer of your rating.

Special PRCP Interviewer's Standards and Guides have been prepared to assist persons conducting interviews. Each Guide contains a detailed explanation of every skill identified in the PRCP. These definitions are now standard throughout the entire Naval Construction Force, and any man, regardless of duty assignment, can turn to these standards and know what is expected in a given skill area.

During an interview, it is imperative that you and your men discuss your capabilities



CREW LEADER Johnson EOZ

CREW SITE PREPARATION AND DITCHING

CREW SIZE 6

TRANSFERS THIS DATE NONE

PROJECT FLEET RECREATION FACILITY SEWAGE Distribution System

DATE 11 JAN 19-

NAME	PRODUCTIVE LABOR CODE															OVERHEAD LABOR CODE (Y)									
	DIRECT					INDIRECT (X)					OTHER (M, D, T)														
	R 13	R 16				X 01					T 04	T 05				Y 02	Y 11								
SMITH	6															2									
GOOD	7																1								
EVANS		7															1								
GILBERT	6					1					1														
ALLEN		6														2									
SULLIVAN		6										2													

DAILY LABOR DISTRIBUTION COMCBPAC-GEN-5300 1 (REV. 6-67)

54.309

Figure 14-4. — Daily labor distribution report form.

openly and honestly. Remember, if you exaggerate, you may be depriving yourselves of valuable and needed training. Then, too, you may be the one selected to do that special job all on your own. Will you be ready?

It will be the responsibility of your supervisors to provide you with the opportunity to learn new skills. This may be done through training or by assigning your team to various types of work whenever possible. You can help by learning what is required in the PRCP Interviewer's Standards and Guides for your rating; then, as you and your men satisfy those requirements, you can report this to your PRCP coordinator. He will then have the information added to your inventory of capabilities. By keeping your PRCP record current, you can avoid the unpleasantness of attending training in areas you are already proficient in. Like practical factors, it is primarily your responsibility to see that this information is kept current and accurate. After all, you will be the first to feel that you are qualified in a new skill.

All PRCP information is ultimately stored in a computer data bank. People who work with computers have developed a very realistic saying: "Garbage in: Garbage out." In other words, the accuracy of reports devised for the Personnel Readiness Capability Program will only be as accurate as the information you provide.

BATTALION SAFETY ORGANIZATION

As a petty officer, you must be familiar with the safety program at your activity. This is important since you cannot function effectively as a petty officer unless you are aware of how you fit into the scheme of safety. You should know who (or what group) arbitrates and establishes the safety policies and procedures you must follow. You should also know who provides guidelines for safety training and supervision. Every naval mobile construction battalion (NMCB) is required by the Naval Construction Force Safety Manual to implement a formal safety organization.

The NMCB's safety organization is composed of two elements as shown in figure 14-5: one to provide for the establishment of safety policy (view A), the other to provide for control and reporting (view B).

SAFETY POLICY ORGANIZATION

The policy organization of a battalion as illustrated in figure 14-5, view A, is broken down into three kinds of committees: (1) the safety policy committee; (2) the supervisor's committee, and (3) the equipment shop or crew committee.

The SAFETY POLICY COMMITTEE is presided over by the executive officer. Its primary purpose is to develop safety doctrine and policy for the battalion. This committee reports to the commanding officer, who must approve all changes in safety policy.

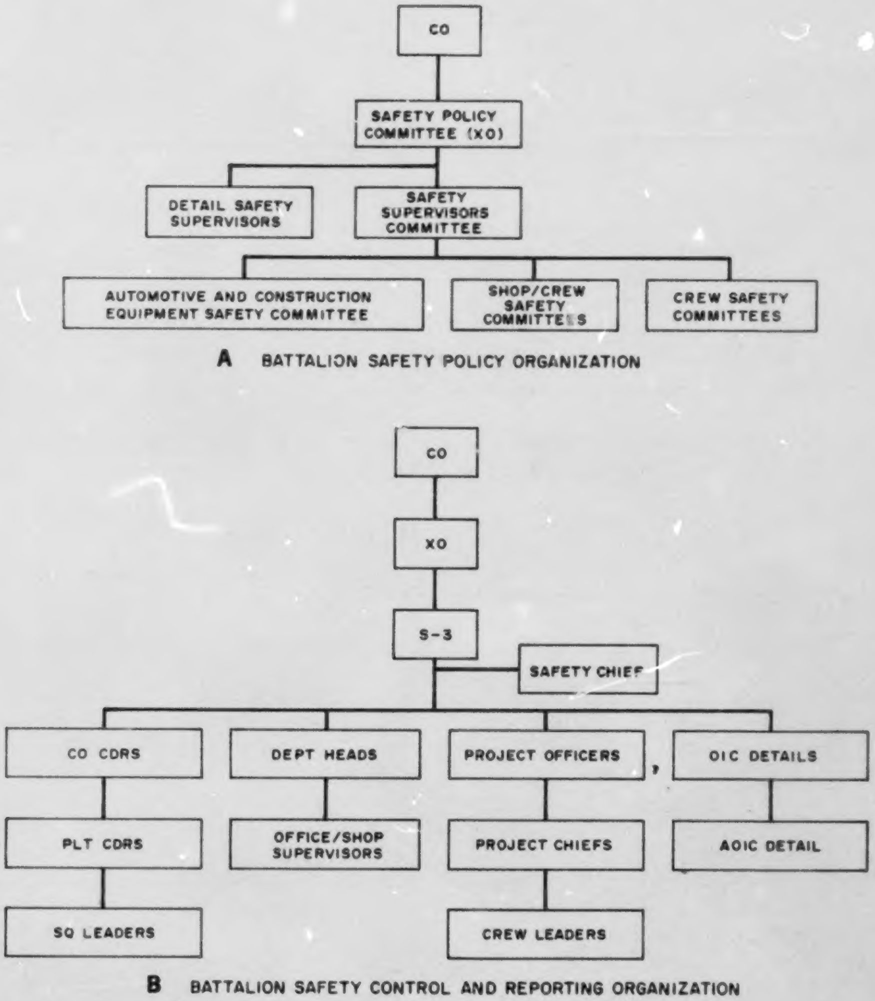
The SUPERVISORS' COMMITTEE is presided over by the battalion's safety chief and is made up of safety supervisors assigned by company commanders, project officers, or officers in charge (OIC's) of detail. This committee provides a convenient forum through which one crew can inform another of its work procedures, safety precautions, and safety suggestions received from crews or individuals. This committee sends its recommendations to the policy committee.

The EQUIPMENT, SHOP, or CREW COMMITTEE is assigned as required. Alfa company has an equipment safety committee presided over by the "A" company chief. The other companies use either the crew or shop committee, both of which are usually presided over by the company or project safety supervisor. The main objective of these committees is to propose changes to the battalion's safety policy, when required, to eliminate unsafe working conditions or prevent unsafe acts. This committee is YOUR CONTACT for recommending safety improvements. In addition to the above, the equipment committee must review all vehicle accident reports, determine the cause of the accidents, and make recommendations for corrective action. As a crew leader, you can expect to serve as a member of either an equipment crew, or shop safety committee. All three of these committees forward reports and recommendations to the supervisor's safety committee.

SAFETY CONTROL AND REPORTING ORGANIZATION

The Safety Control and Reporting Organization follows the regular chain of command. As a crew leader, you will be held accountable for industrial accidents involving personnel under your supervision. The number and types of accidents will be taken into account by your supervisor in rating your ability to supervise. It is the direct responsibility of each crew leader to:

1. Ensure that every man under his supervision is thoroughly familiar with the trade


CO
SAFETY POLICY COMMITTEE (XO)
DETAIL SAFETY SUPERVISORS
SAFETY SUPERVISORS COMMITTEE
AUTOMOTIVE AND CONSTRUCTION EQUIPMENT SAFETY COMMITTEE
SHOP/CREW SAFETY COMMITTEES
CREW SAFETY COMMITTEES
A BATTALION SAFETY POLICY ORGANIZATION
CO
XO
S-3
SAFETY CHIEF
CO CDRS
DEPT HEADS
PROJECT OFFICERS
OIC DETAILS
PLT CDRS
OFFICE/SHOP SUPERVISORS
PROJECT CHIEFS
AOIC DETAIL
SQ LEADERS
CREW LEADERS
B BATTALION SAFETY CONTROL AND REPORTING ORGANIZATION

73.350

Figure 14-5.—Battalion safety policy organization.

procedures, techniques, rules, and regulations applicable to the man's safe conduct and work performance, and to make sure the man has a general understanding of all pertinent safety regulations.

2. Ensure that all subordinates make proper use of personal protective equipment and clothing and, if necessary, personally demonstrate its proper use.

3. Personally direct or request from proper authority the correction of unsafe conditions and unsafe practices encountered by those under his supervision, and carry out requests to a satisfactory conclusion.

4. In case of accident, get the injured to proper medical care as quickly as possible.

5. Investigate all accidents involving his men, determine the causes (carelessness, thoughtlessness, negligence, and so on are not acceptable), submit required written reports, and promptly apply remedial measures in the form of on-the-job training of all subordinates similarly exposed,

and remove or have permanently corrected all defective tools, materials, machinery, or environment contributing to cause of the accident.

In addition to your responsibilities as a crew leader you, as an individual, are responsible for carrying out safe work practices as directed by higher authority. It is your responsibility to immediately report to your supervisor any unsafe practices or conditions you observe. To aid you in carrying out your responsibilities, you will receive assistance from your supervisors, through special training, and by participation in standup safety meetings. It is also important to note that ALL HANDS are encouraged to submit safety ideas through the safety policy chain of command.

KEY SAFETY PERSONNEL

For success in carrying out your responsibilities in the safety program, you must know who is responsible for what in regard to safety. The three key jobs in a battalion's safety program are: safety officer, safety chief, and safety supervisor.

The SAFETY OFFICER in a battalion is normally the Operations Officer (S3). He is responsible for ensuring that the battalion's safety program meets the requirements of the Naval Construction Force Safety Manual and its references. The Safety Officer is responsible for:

1. Providing continuous safety inspection of all shops and jobsites.
2. Maintaining a safety reference library.
3. Providing assistance in the training of safety supervisors and crew leaders.
4. Ensuring accurate accident reporting.
5. Ordering any safety equipment required for a shop or project when such equipment is not a normal allowance item.

The SAFETY CHIEF is normally an E-7 or E-8 and is assigned full-time to safety. He assists the safety officer in all his duties and is the one you will have the most contact with. He will help you get the training necessary for you and your crew. A major responsibility of the safety chief is to ensure that the battalion's safety program is enforced. If you have a question on safety, he should be able to find the answer. It's important to remember that the safety chief, the safety officer or any other person in a position of authority has the power to stop a job when he has determined an unsafe condition exists—until such condition is corrected.

The SAFETY SUPERVISOR is normally a first class petty officer, who is assigned this collateral duty by his company commander, project officer, or detail OIC. He directs, in an advisory capacity, the safety program of the company project or detail. His responsibilities include the following:

1. Indoctrination of new men.
2. The assembling, coordinating, and dissemination of information for use of crew leaders in their Standup Safety Meeting.
3. Advising the company commander/project officer/detail OIC concerning the safety program, and recommending changes required to eliminate unsafe work practices and hazardous conditions.
4. Compiling accident statistics for his company/project/team and analysis comparing crew leaders. Records should be kept on a monthly basis and all crew leaders informed as to their standing.
5. Reviewing personal protective equipment requirements of the men and advising crew leaders on the correct type of safety equipment to use, where to obtain it, how to use it, and so on.
6. Assuring that crew leaders are provided with sufficient safety information for use in instructing men in their crew.
7. Reviewing all accident reports submitted to the Safety Office, appraising the quality of the report, and assisting the company commander/project officer/detail OIC in making constructive use of the information contained therein.

CHAPTER 15

BASIC ELECTRONIC COMPONENTS AND CIRCUITS

Although there have been many attempts to explain the difference between the meanings of the terms "electricity" and "electronics," they are more alike than they are different. For instance, electricity and electronics are both concerned with the use of electricity to operate equipment. The field of electricity is usually concerned with magnets, generators, motors, lights, and heaters; the field of electronics is concerned with the use of electricity in radio, television, radar, telephone, and other equipment in which electron tubes or transistors are needed.

Current and voltage cannot tell the difference between an electrical circuit and an electronic circuit. The components that have been built into the circuit determine how the current and voltage will be used to make the electrical or electronic equipment work. One of the most recently developed electronic components is the transistor. Transistors are constructed from solid materials, classified as semiconductors, whose resistance to the flow of electrons is between that of insulators and conductors.

Any circuit can be thought of in terms of the effects that resistors, capacitors, and inductors (coils) have on current or voltage. The effect that a resistor has on current or voltage is measured in terms of its resistance; the effect of a capacitor is measured in terms of its capacitance; and the effect of a coil is measured in terms of its inductance. The effect that each of these measurable properties has on current or voltage depends on whether the current is direct or alternating and, if alternating, how fast the current or voltage is changing (frequency).

As a Construction Electrician, therefore, you will find it necessary to test resistors, capacitors, and inductors in an electrical or electronic circuit by measuring or otherwise determining the effects of their properties on the current or voltage of the circuit.

RESISTORS AND CAPACITORS

As you already know, current passing through a resistor generates heat. If too much heat is generated, the resistor will be damaged. Wire in the wound resistor will become open, or some of the carbon in the composition resistor will burn away, thus changing the resistor value.

RESISTOR RATINGS

The current-carrying capacity of a resistor is rated according to the amount of heat it can safely release in a given amount of time. Therefore, a resistor cannot be used in a circuit where current causes heat to build up faster than the resistor can dissipate it.

Since heat is a form of energy, the heat-releasing rate of a resistor is measured in energy units called watts. A composition resistor is usually rated at 1/3, 1/2, 1 or 2 watts. The power ratings of wirewound resistors are larger.

RESISTOR TOLERANCES

A resistor rarely measures the exact number of ohms specified by its label or color codes. The amount it varies is called tolerance. Resistor tolerance is given as a percentage value which indicates the amount that a resistor may vary above or below its specified value. Standard tolerances for composition resistors are 5, 10 and 20 percent. Wirewound resistors may have tolerances as low as 1 or 2 percent.

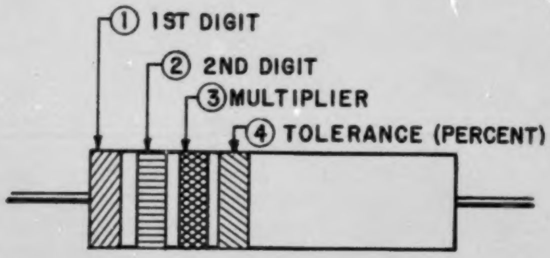
Take a 1,000-ohm resistor with 10 percent tolerance as an example. Ten percent of 1,000 is 100 ohms. Because of the tolerance factor, this resistor will measure somewhere between 100 ohms above and 100 ohms below the labeled value of 1,000 ohms. The range is from 900 to 1,100 ohms.

Resistor tolerance is not an indication of poor manufacturing. Closer tolerances can be achieved, but at greater expense. A resistor with a 20 percent tolerance will cost less than one with a 10 percent tolerance.

RESISTOR COLOR CODES

A wirewound resistor is usually marked with its value in ohms and tolerance in percentage. A color code is used for carbon or composition resistors. For several years, resistance values have been coded by three colored bands painted around the body of the resistor. If the tolerance is either 5 or 10 percent, a fourth color band is used; if 20 percent there is no fourth color band. Positions of the bands are as shown in figure 15-1.

The first two color bands (① and ② of figure 15-1) indicate the first two digits in the colors and numbers table (table 15-1). The third band ③ is the multiplier and indicates the number of zeros that follow the first two digits. The fourth band ④ indicates the tolerance and is either gold for 5 percent, or silver for 10 percent.



20.373:.374

Figure 15-1. — Color-coded resistor.

Table 15-1. — Colors and Numbers Used to Code Resistors

COLOR	DIGIT	DIGIT	MULTIPLIER	TOLERANCE (percent)
Black	0	0	1	
Brown	1	1	10	
Red	2	2	100	
Orange	3	3	1,000	
Yellow	4	4	10,000	
Green	5	5	100,000	
Blue	6	6	1,000,000	
Violet	7	7	10,000,000	
Gray	8	8	100,000,000	
White	9	9	1,000,000,000	
Gold			.1	5
Silver			.01	10
No color				20

20.373:.374

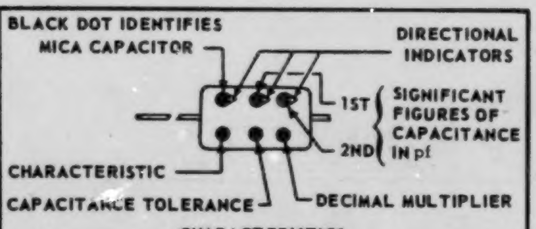
Always use a replacement resistor with a wattage rating equal to or higher than that of the original — never lower. Otherwise, the replacement will burn out. You can use the physical size of the resistor as a guide, if the replacement is the same type (carbon, metallized, or wirewound) as the original. The replacement should be the same physical size or larger.

CAPACITOR COLOR CODING

The value of many capacitors is printed on them, but some use a color-coded system. The color code is the same as that for resistors, but the methods of marking the capacitors differ. The method for fixed mica capacitors is shown in figure 15-2.

A black dot in the upper left corner signifies that the capacitor has a mica dielectric. The center dot in the upper row indicates the first significant figure, and the upper right dot indicates the second significant figure of the capacitance value in picofarads (pF). The right dot in the lower row indicates the decimal multiplier or number of zeros to be added to the right of the two significant figures. The center dot (lower row) specifies the tolerance, which is the possible deviation of the actual capacitor value from that given by its dot markings. The left dot on the lower row deals with the temperature coefficient and applications. As an example, take a capacitor with upper row dots colored black, red, and green (reading from left to right according to the directional indicator). This is a mica capacitor; the significant figures are 2 and 5. Suppose the lower row of dots (reading from right to left) are brown, red, and red. The brown dot requires the addition of one zero to the value of 25, resulting in 250 pF. The red center dot indicates that the actual capacitor value may vary from 250 pF by plus or minus 2 percent. The left red dot means a bypass or silver mica capacitor. Some mica capacitors have only three dots, indicating the first and second significant figures and the multiplier. Their tolerance is 20 percent and their rating is 500 volts. Try reading some of the capacitor values you see in electronic devices when they are exposed to view. Learning to read capacitor values is a matter of practice, much like reading resistor values. There are other types of capacitors whose identification codes vary. See appendix IV of Basic Electricity, NAVTRA 10086-B for the explanation of these codes. Also see appendix II of this manual for a list of prefixes which indicate multiples of basic measuring units.

COLOR	CAPACITANCE		TOLERANCE	CHARACTERISTIC
	SIGNIFICANT FIGURE	DECIMAL MULTIPLIER		
BLACK	0	1	20 PERCENT	A
BROWN	1	10		B
RED	2	100	2 PERCENT	C
ORANGE	3	1,000		D
YELLOW	4			E
GREEN	5			F
BLUE	6			G
VIOLET	7			
GRAY	8			
WHITE	9			
GOLD		0.1	5 PERCENT	
SILVER		0.01	10 PERCENT	



CHARACTERISTICS

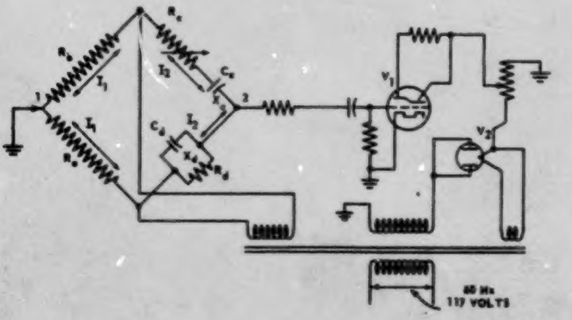
A - ORDINARY MICA BYPASS
B - SAME AS A-LOW LOSS CASE
C - BYPASS OR SILVER MICA (±200 PARTS/MILLION/C)
D - SILVER MICA (±100 PARTS/MILLION/C)
E - SILVER MICA (0 TO +100 PARTS/MILLION/C)
F - SILVER MICA (0 TO +50 PARTS/MILLION/C)
G - SILVER MICA (0 TO -50 PARTS/MILLION/C)

20.376(71)

Figure 15-2.—Color code for fixed mica capacitors.

CIRCUIT TESTING

Capacitance, inductance, and resistance are measured precisely by alternating current bridges. These bridges are composed of capacitors, inductors, and resistors in a wide variety of combinations. The bridges operate on the principle of the Wheatstone bridge, in which an unknown resistance is balanced against known resistances. The unknown resistance is calculated in terms of the known resistance after the bridge is balanced. One type of capacitance bridge circuit appears in simplified schematic form in figure 15-3. When the bridge is balanced by adjusting the two variable resistors, no a-c voltage is developed across the input of indicator tube V1.



20.344

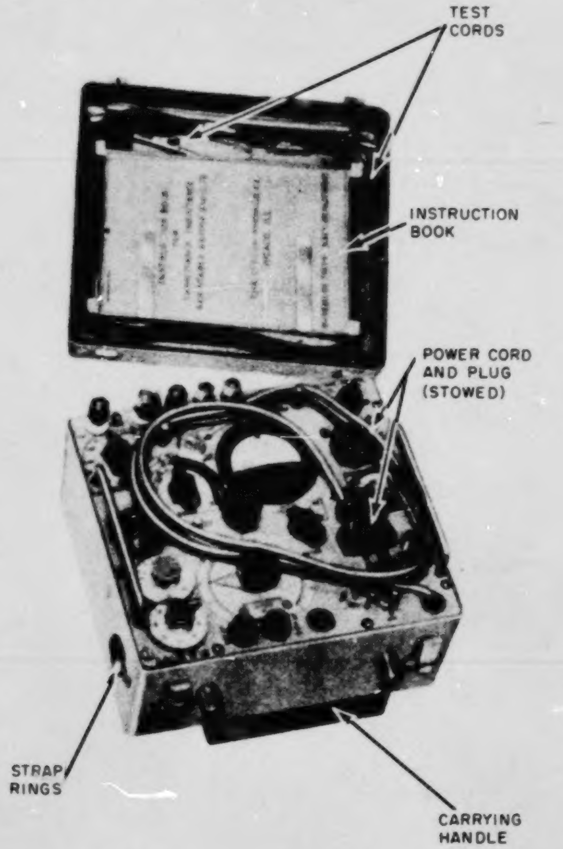
Figure 15-3.—Simplified schematic of capacity checker.

In the basic Wheatstone bridge circuit using d-c voltages and simple resistances, the balance is obtained when the voltage drops are equal across the ratio arms. In the a-c capacity bridge, it is insufficient to have equality of voltage drops in the ratio arms. The phase angle between current and voltage in the two arms containing the capacitors also must be equal in order to obtain a balance. When a balance is obtained, the current is equal on both sides of the bridge circuit.

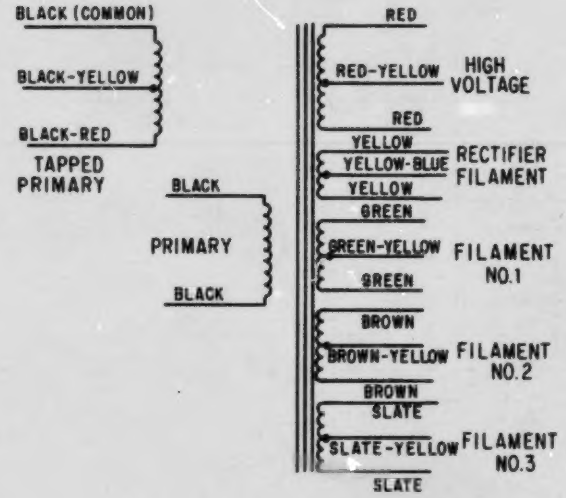
The capacitance-inductance-resistance bridge of figure 15-4 not only measures capacitance, resistance, and inductance values, but is also used for special tests, such as the turns ratio of transformers and capacitance quality tests. It is a self-contained instrument, except for a source of line power. It has its own source of 1000-Hz bridge current with a sensitive bridge balance indicator, an adjustable source of direct current for electrolytic capacitor and insulation resistance testing, and a meter with suitable ranges for leakage current tests on electrolytic capacitors.

TRANSFORMER TESTING

Transformers ordinarily are tested by checking for shorts, measuring resistance of the individual windings, and measuring voltage outputs of each winding. The technical manual for the


TEST CORDS
INSTRUCTION BOOK
POWER CORD AND PLUG (STOWED)
STRAP RINGS
CARRYING HANDLE

20.345
Figure 15-4.—Capacitance-inductance-resistance bridge, type ZM-11/U.


BLACK (COMMON)
BLACK-YELLOW
BLACK-RED
TAPPED PRIMARY
BLACK
PRIMARY
BLACK
RED
RED-YELLOW
HIGH VOLTAGE
RED
YELLOW
YELLOW-BLUE
RECTIFIER FILAMENT
YELLOW
GREEN
GREEN-YELLOW
FILAMENT NO.1
GREEN
BROWN
BROWN-YELLOW
FILAMENT NO.2
BROWN
SLATE
SLATE-YELLOW
FILAMENT NO.3
SLATE

20.379(71)
Figure 15-5.—Color coding of small power transformer leads.

equipment that contains a transformer describes the transformer, specifies the terminals to test for each winding, and tells what each measurement should be. Transformers, of the size used in electronic equipment, usually are color-coded as shown in figure 15-5. In an untapped primary, both leads are black. If the primary is tapped, one lead is common and is colored black; the tap lead is black and yellow, and the other lead is black and red.

On the transformer secondary, the high-voltage winding has two red leads, if untapped, or two red leads and a yellow and red tap lead, if tapped. On the rectifier filament windings, yellow leads are used across the entire winding, and the tap lead is yellow and blue. If there are other filament windings, they may be green, brown, or slate. The tapped wire is yellow in combination with one of the colors just named; that is, green and yellow, brown and yellow, or slate and yellow.

An easy way to check a suspected malfunctioning transformer is to measure its voltage output. Use a voltmeter to measure across the proper terminals, and compare the reading obtained with the proper voltage given in the manufacturer's manual. If only one reading is in error, then only that winding is at fault. If all readings are in error, the trouble could possibly be a high- or low-input voltage. Consequently, always measure the input voltage as well as the output voltage.

If the voltage measures high or low at any of the output windings, the next step is to measure the resistance of each winding. Make sure the connections to the terminals are disconnected first. Power to the equipment must be secured prior to disconnecting a transformer. Once the leads are free, measure the resistance across each winding with an ohmmeter set to the proper scale. Check each winding carefully, including any center taps. Next, set the ohmmeter to a high scale and test for shorts between windings and between windings and ground.

If no faults are indicated by the voltage or resistance readings, or by the tests for shorts, assume that the transformer is in proper operating condition. Then reconnect it in the circuit.

If a replacement is required, use only the one recommended by the manufacturer's manual. Always test for shorts and check the resistance of a new transformer before installing it in the circuit.

IDENTIFICATION OF CHASSIS WIRING

Standard colors used in chassis wiring for the purpose of circuit identification of the equipment are given below. For electrical and electronic symbols, refer to Graphic Symbols for Electrical and Electronic Diagrams (American National Standards Institute) Y32.2, March 1971.

Circuits	Colors
Grounds, grounded elements and returns	Black
Heaters or filaments, off ground	Brown
Power supply B plus	Red
Screen grids	Orange
Cathodes	Yellow
Control grids	Green
Plates	Blue
Power supply, minus	Violet (Purple)
A-c power lines	Gray
Miscellaneous, above or below ground returns, AVC, and so forth	White

DIODES

A diode is an electrically operated device that has two elements or electrodes. When a voltage of the proper polarity is applied to the electrodes, current flows easily through the diode. Reversing the polarity, however, makes current flow difficult or prevents it altogether.

There are two general classes of diodes: electron tube or solid state. The electrodes of an electron tube diode are enclosed in a glass or metal envelope. A solid state diode is made of two dissimilar metals or two different semiconductors. Depending on the polarity of the applied voltage, current flows or does not flow across the junction formed by the metals or the semiconductors. A semiconductor diode is made of the same materials as those in transistors, usually germanium or silicon.

ELECTRON TUBE DIODES

The major components of an electron tube diode are two polarixed electrodes called anode and cathode. These electrodes are mounted inside an evacuated envelope and fitted into an insulated base. Cathodes are made of materials that emit electrons rapidly and easily; anode materials do not.

When heated, the cathode immediately starts to emit electrons. Although the emission is low, you can measure the potential between the anode and cathode (before an external potential difference is applied between them) by comparing the stable or reference state of the anode material to the electron emission from the cathode material.

At the instant a difference of potential is applied externally between the anode and the cathode, an electric field exists between them. Under the direct influence of the electric field, electrons flow toward the anode, and continue to flow as long as the field exists. The intensity of current flow is directly proportional to the potential difference between the cathode and anode.

Since anode material does not tend to emit electrons, current flow from the anode to cathode does not normally occur. Hence, the electron tube diode acts as a one-way valve or switch.

Should a difference of potential (high in value and reversed in polarity) be placed across an electron tube diode, the dielectric material between anode and cathode may break down, resulting in an excessive quantity of reverse current flow. The breakdown of dielectric material in an electron tube may be closely compared to the breakdown of a capacitor's dielectric. Each is due to excessive electric field strength or extraordinarily high difference of potential across elements of the device. In each case of breakdown there exists some physical means of conducting current between the elements. In capacitors this means is the dielectric; in electron tubes, it is a form of dielectric. Specifically, in electron tubes, it is the evacuated envelope which is not an absolute void or a perfect vacuum.

Operation

Since the evacuated envelope of an electron tube diode is not a perfect vacuum, some matter remains in the existing space. When the cathode is heated, it begins to emit electrons. Upon application of an electric field, these electrons are directed through the so-called vacuum to the anode, through the source, and back to the cathode.

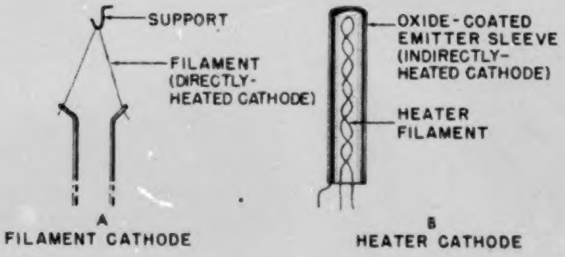
In some cases electron tube diodes are constructed without a means for heating the cathode. Called cold cathode diodes, they work on the principle that a difference of potential placed across the anode and cathode creates an electric field. Since cathode material emits electrons, some are started on their path to the anode. These diodes are filled with an inert gas, such as neon, argon, krypton, or xenon. When electrons flow in this gas, it becomes ionized, or electrically charged. As current flow through an inert gas diode increases, more energy is dissipated in ionizing the gas. Within the limits established by the quantity and type of gas, the diode will maintain a constant voltage drop across its elements, though current flow through them varies.

Since some energy is dissipated in the form of heat while a cold cathode electron tube operates, the cathode temperature does rise. Therefore, the term "cold cathode" is not completely accurate and only indicates that the electron tube lacks a cathode heating element.

Construction

Cathodes are heated in one of two ways—directly or indirectly. In a directly heated cathode, the current that furnishes the heat flows directly through the emitting material. In an indirectly heated cathode, the heating current flows through a heating filament and transfers heat to the emitting material (cathode). Figure 15-6 illustrates the construction and methods of heating the two types of cathodes.

The directly heated cathode, commonly called a filament, is fairly efficient and can emit large amounts of energy. However, due to the small mass of the filament wire, the filament temperature fluctuates with changes in current flow. If an a-c source is used to heat the filament, an undesired hum may be introduced into the circuit. The hum is especially evident in low level signal circuits.

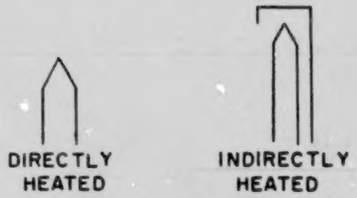

SUPPORT
FILAMENT (DIRECTLY-HEATED CATHODE)
OXIDE-COATED EMITTER SLEEVE (INDIRECTLY-HEATED CATHODE)
HEATER FILAMENT
A
FILAMENT CATHODE
B
HEATER CATHODE

13.21

Figure 15-6.—Methods of heating the cathodes of electron tubes.

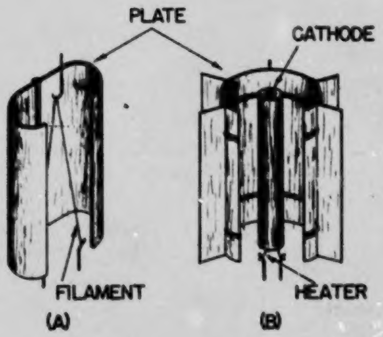
A relatively constant rate of emission under mildly fluctuating current conditions may be obtained with an indirectly heated cathode. This type of cathode is in the form of a cylinder; in its center is a twisted, electrically insulated wire, called the heater. The cathode is maintained at the correct temperature by heat radiated from the heater. The emitting material in this type of cathode remains at a relatively constant temperature, even with an a-c heater. Figure 15-7 illustrates the schematic symbols for directly and indirectly heated cathodes.

The cathode is normally placed in the center of the tube structure, and is surrounded by the anode, also called the plate. Figure 15-8 shows cutaway views of two types of diodes. One has a directly heated cathode or filament, the other



179.141

Figure 15-7.—Schematic symbols for directly and indirectly heated cathodes.



179.142

Figure 15-8.—Cutaway views of directly and indirectly heated diodes.

an indirectly heated cathode. (The heater of the indirectly heated cathode does not count as an element of the diode.) The plate material, besides not tending to emit electrons, must be able to dissipate the heat generated by electrons striking the plate.

The schematic symbols for diode tubes are shown in figure 15-9. In some cases, two or more diodes are included in the same envelope to conserve space. A tube which contains two plates and one or two cathodes is called a duo-diode or twin diode. Figure 15-10 illustrates the construction and schematic symbols of duo-diode electron tubes.

As a rule, electron tubes are not expected to last as long as resistors, capacitors, or other circuit components. This is due, in large part, to wearing out or breaking down of the filament or heater. To make it easy to remove and replace a tube, the base of the tube (figure 15-10) is constructed in the form of a plug, which fits into a socket on the chassis. The electrical connections between the tube elements and the circuit are completed through the plug terminals, called pins.

There are various types of tube bases, containing different numbers and sizes of pins. Each type of tube base has a guide or key to prevent the tube from being plugged into the socket improperly. To make circuit tracing easy, the tube pins are assigned numbers. At the BOTTOM of the tube or socket, the pins are numbered in a clockwise direction, beginning with No. 1 at the key or guide. The pin numbering systems for several types of tubes are shown in figure 15-11.

Ratings

Each diode has certain voltage, current, and power ratings. By definition, a rating is the limiting value which must not be exceeded to prevent permanent damage to a device, such

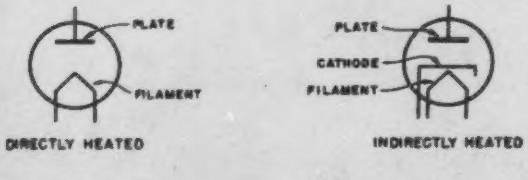
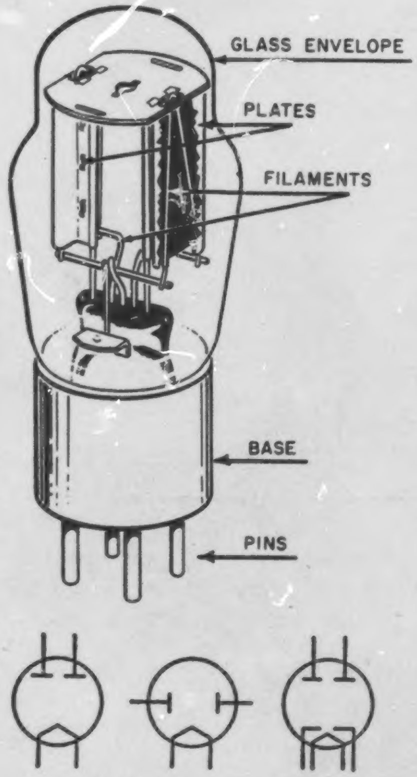
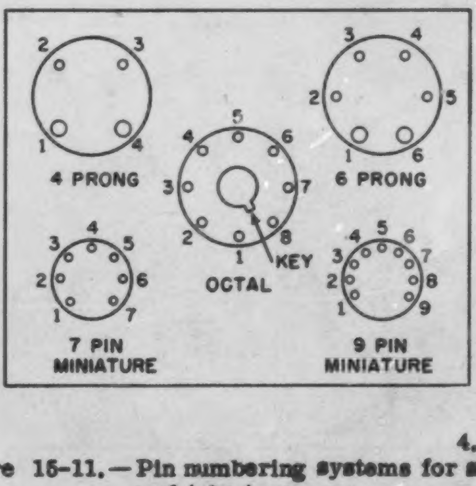


PLATE
FILAMENT
DIRECTLY HEATED
PLATE
CATHODE
FILAMENT
INDIRECTLY HEATED

4.140
Figure 15-9.—Schematic symbols used to represent diode tubes.


GLASS ENVELOPE
PLATES
FILAMENTS
BASE
PINS

4.140(20C)
Figure 15-10.—Construction and schematic symbols of duo-diodes.


2
3
1
4
4 PRONG
3
4
2
5
1
6
6 PRONG
5
4
6
3
7
2
8
1
KEY
OCTAL
4
3
5
2
6
1
7
7 PIN MINIATURE
4
5
6
3
7
2
8
1
9
9 PIN MINIATURE

4.141
Figure 15-11.—Pin numbering systems for several tube types.

as the diode. The filament or heater voltage and current values must be correct for proper operation of an electron tube. If heater current is too low, the cathode will not emit enough electrons. Too much heater or filament current may reduce the life of the tube or destroy the heater or filament.

Other important diode electron tube ratings are:

PLATE DISSIPATION — the maximum average power, in the form of heat, which the plate may safely dissipate.

MAXIMUM AVERAGE CURRENT — the highest average plate current which may be handled continuously, based on the tube's permissible plate dissipation.

MAXIMUM PEAK PLATE CURRENT — the highest instantaneous plate current that a tube can safely carry in the direction of normal current flow.

PEAK INVERSE VOLTAGE (PIV) — the highest instantaneous plate voltage which the tube can withstand, acting in a direction opposite to that in which the tube is designed to pass current (plate negative — cathode positive).

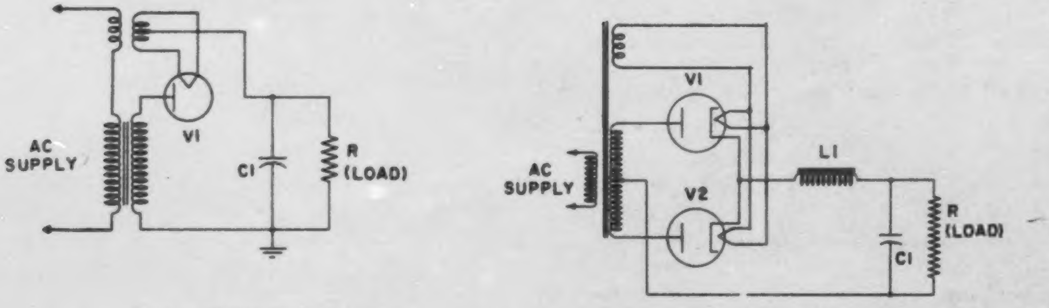
DIODE RECTIFIERS

The electron tube diode is a rectifier; that is, a device for converting alternating current to direct current. Alternating current constantly reverses direction as it flows through a wire. Each time the current reverses direction, it alternately carries electrons to the anode, making it negative, and away from the anode, making it positive. The anode attracts electrons from the cathode only during the periods when it is positive.

Figure 15-12, view A, shows a diode in a half-wave rectifier circuit or a circuit that rectifies only one-half of the a-c cycle. The transformer steps down the voltage to provide filament voltage for the diode and heater voltage. Alternating current flows through the secondary winding; the output of the circuit is pulsating direct current. When the plate of the diode in this circuit is positive, it attracts electrons from the filament and current flows through the tube. Electrons travel from the plate through the transformer and return to the filament by way of the load resistor. The filament then becomes the positive terminal for the power supply; the transformer lead becomes the negative terminal. As the alternating current changes direction of electron flow, the plate becomes negative and no current flows through the diode. Since current flows through the diode during half of the a-c cycle only, a pulsating d-c is produced. This current can be smoothed out by means of a filter which enables current to flow when the rectifier is not operating.

For a more constant flow of current, both halves of the a-c cycle are rectified. In this case, you have a full-wave rectifying circuit that has two diodes or one twin diode. The high-voltage secondary of the transformer is tapped in the center. One plate goes to one side of the secondary; the other plate to the opposite side of the secondary. (See figure 15-12, view B.)

When the plate of diode V1 is positive, it pulls electrons from the filament and current



HALF WAVE

FULL WAVE

20.37:.40.1

Figure 15-12. — Electron tube rectifier circuits.

flows through V1 to the plate and out through the center tap of the transformer. As the alternating current starts to flow in the other direction, the plate of diode V1 becomes negative and that of diode V2 becomes positive. Electrons are now attracted to the plate of V2. Current flows through V2 to the plate and out through the center tap of the transformer. Electron flow through the center tap is always in the same direction. Both halves of the a-c cycle are rectified and current flows all the time.

SOLID STATE DIODES

Conductors are substances made up of atoms whose outer-orbit electrons are loosely bound. At ordinary room temperature, enough heat energy is applied to the atoms to permit large numbers of these electrons to be liberated (free electrons), and to drift aimlessly about from one atom to another. If a voltage is applied to the end of a conductor, free electrons will stream to the positive side as other electrons enter from the negative end. It is in this way that current flows through a conductor. As carriers of electricity, the electrons move from the negative to the positive side of the conductor.

In an insulator, on the other hand, the outer-orbit electrons are tightly bound and there are few free electrons. As a result, little current will flow when a voltage is applied to the end of the insulator. If the voltage is high enough to rupture the insulator, however, current will flow, which may be in the form of an arc.

There are solid substances, known as semiconductors, whose outer-orbit electrons are not loosely bound, as in conductors, or tightly bound, as in insulators. Two examples are germanium and silicon. If a voltage is applied to a semiconductor, current will flow, but not as readily as in a conductor.

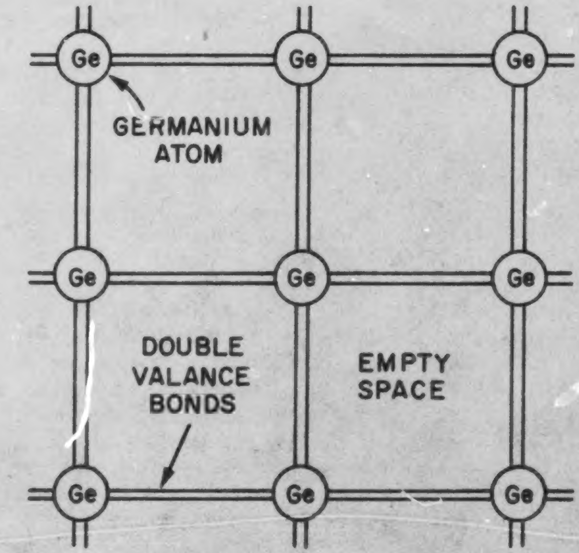
Atomic Theory

The germanium atom has a nucleus of 32 protons and 32 orbiting electrons arranged in four concentric shells or orbits. The three shells closest to the nucleus are completely filled with 28 electrons, the outermost shell containing the remaining 4 electrons. The electrons of the outermost shell are called the valence electrons; they determine the chemical and electrical properties of the atom.

Since the outermost electrons are loosely bound to the nucleus at ordinary room temperature, many of them escape and wander as free electrons. Where an electron escapes from its atom, a hole is left in its place. The loss of the electron and the appearance of the hole converts the neutral atom into a positive ion. Thus, the hole is said to have a positive charge that is equal and opposite to the negative charge of the free electron.

When a hole appears in an atom, an electron from a neighboring atom may move in to fill this hole, leaving a hole in its place. Thus, a hole moves from the first atom to the second atom just as a free electron moves, except that the hole carries a positive charge instead of a negative charge. A rise in temperature or the presence of an electric field can force free electrons to move toward a positive pole. As free electrons move toward the positive pole, holes move toward the negative pole.

In a crystal of pure germanium, the atoms arrange themselves in a geometric pattern, each atom being relatively far from its neighbor. Though the crystal is a three-dimensional structure, figure 15-13 shows two dimensions only. The two parallel lines linking each germanium atom (Ge) to its neighbor represents a double-valence bond made up of one valence electron from each atom. Each germanium atom is linked up with four other atoms, thus accounting for its



73.372

Figure 15-13.—Germanium crystal.

four valence electrons. When an electron escapes from one of the double valence bonds, it leaves a single-valence bond and a hole.

The number of free electrons in a germanium crystal can be increased by adding a small amount of an impurity, such as arsenic. An atom of arsenic has five valence electrons. It replaces one of the germanium atoms in the crystal, combining with its four neighbors and leaving one of its electrons free, as shown in figure 15-14, view A. Such a germanium crystal is called a N-(negative) type.

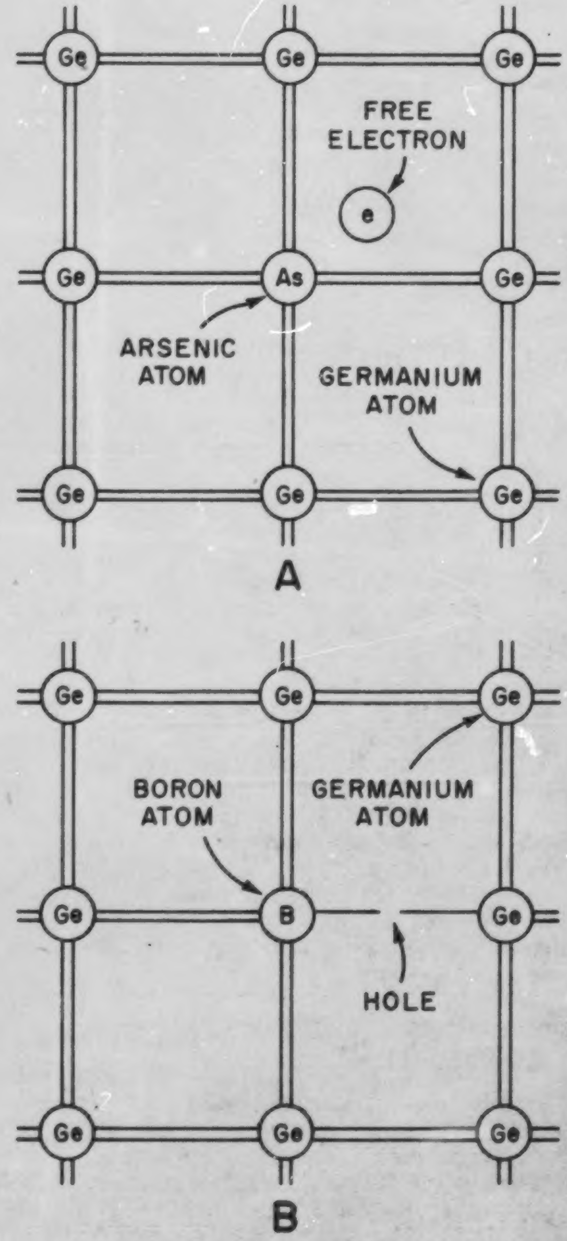
Similarly, the number of holes in a germanium crystal can be increased by adding a small amount of an impurity, such as boron. A boron atom has three valence electrons. When it replaces one of the germanium atoms in the crystal, the boron atom forms double-valence bonds with three of its germanium neighbors. With its fourth neighbor, it forms a single-valence bond and leaves a hole for the missing electron as shown in figure 15-14, view B. Such a germanium crystal is called a P-(positive) type.

The Crystal Diode

In view A of figure 15-15, a P-type germanium crystal joins an N-type germanium crystal to form a P-N junction diode. Each N-P type of crystal contains a number of free electrons (indicated by -) and an equal number of holes (indicated by +). The N-type crystal, however, has many more free electrons introduced by the five-valence impurity; the P-type crystal, on the other hand, has many more holes introduced by the three-valence impurity. With a battery connected as shown in figure 15-15, view B (positive lead connected to the P-type crystal and negative lead to the N-type crystal) all the free electrons tend to move toward the positive lead and all the holes toward the negative lead.

Thus most of the free electrons and holes tend to move toward the junction between the two crystals. Because opposite charges attract, the electrons and holes rush toward each other and recombine as a free electron drops into a hole. The effect of the applied voltage is to produce more free electrons in the N-type crystal and more holes in the P-type crystal. Hence, there is a continuous movement of electrons and holes through the crystals, creating a relatively high current flow through the entire circuit as indicated by the arrows. When applied as shown in figure 15-15, view A, the voltage is said to be in the forward direction.

Now suppose the battery is reversed as shown in figure 15-15, view C. Again the free electrons

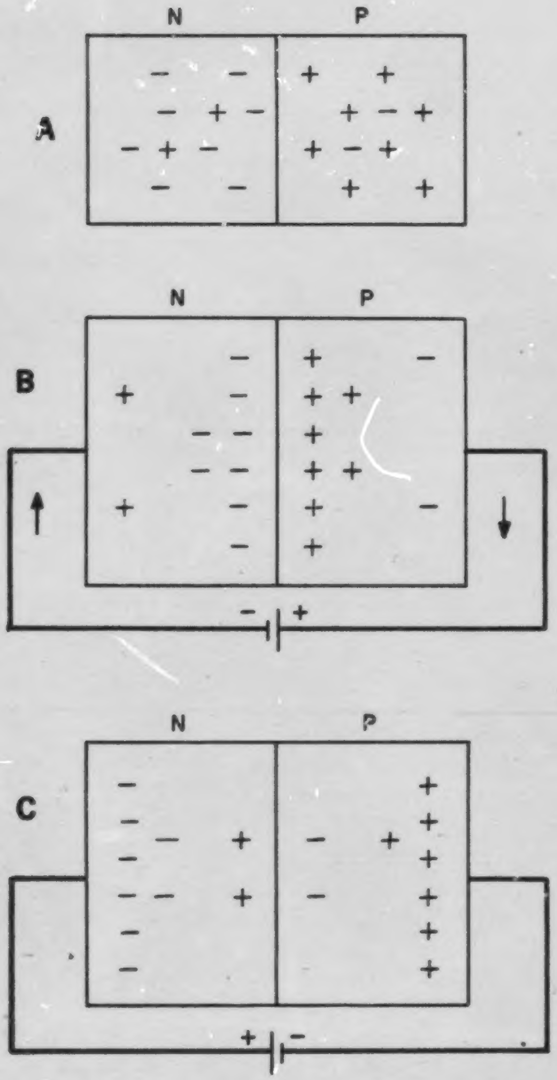


73.373

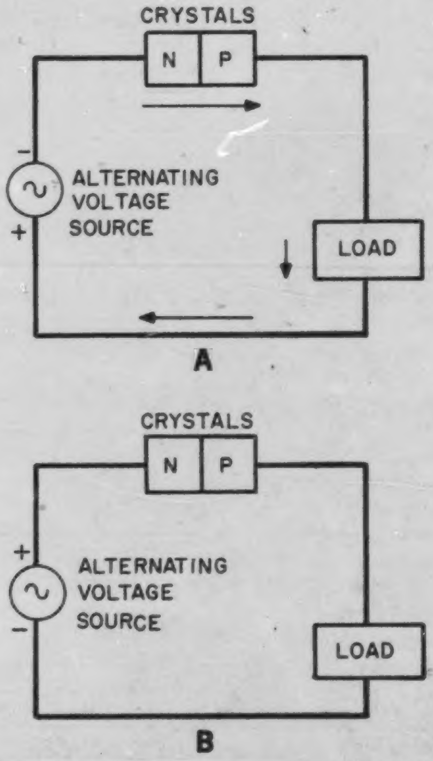
Figure 15-14.—(A) Structure of N-type crystal; (B) Structure of P-type crystal.

flow toward the positive lead and the holes flow toward the negative lead. But since there are relatively few electrons and holes at the junction of the crystal, the flow of current across the junction is small and so is the current flow in the circuit. When applied as shown in figure 15-15, view C, the voltage is said to be in the reverse, or nonconducting, direction.

If a source of alternating current is applied to the crystals connected in series with a load, the voltage for one-half cycle will be in the forward direction (figure 15-16, view A) and current will flow through the circuit. During the next half-cycle the voltage will be in the reverse direction (figure 15-16, view B) and no current will flow. This is how an N-P junction diode rectifies alternating current just as the electron-tube diode does.



73.374
Figure 15-15.—(A) Distribution of free electrons and holes when N-type and P-type crystals are joined together; (B) Distribution of free electrons and holes when voltage is applied in forward direction; (C) Distribution of free electrons and holes when voltage is applied in reverse direction.

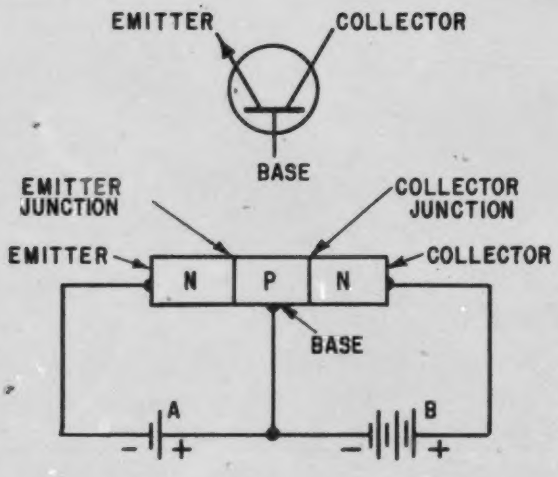


73.375
Figure 15-16.—The junction diode as a rectifier; (A) Voltage applied in forward direction. Arrows indicate direction of current flow; (B) Voltage applied in reverse direction. There is no current flow.

TRANSISTORS

In figure 15-17, a thin P-type crystal is sandwiched between two N-type crystals. The emitter terminal is on the left-hand N-type crystal, the collector terminal on the other N-type crystal, and the base terminal on the P-type crystal. The junction between the left-hand N-type crystal and the P-type crystal is the emitter junction; the one between the right-hand N-type crystal and the P-type crystal is the collector junction. The entire sandwich with its terminals is a junction transistor. The junction transistor consists of a single unit with the three distinct regions or layers being doped with controlled amounts of impurities. The schematic symbol for a transistor is also shown in figure 15-17.

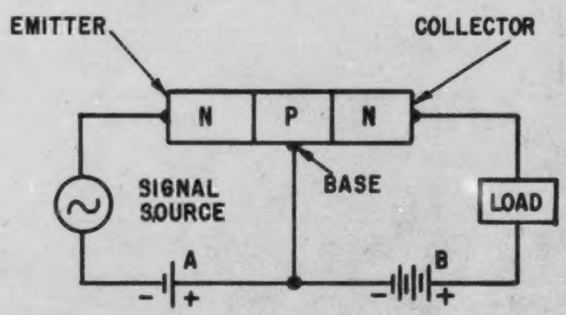
Note that the voltage from battery A is applied in the forward direction, relative to the emitter junction. Thus the impedance of this junction is low. On the other hand, the voltage of battery B is applied in the reverse direction relative to the collector junction. Therefore its impedance is high. As a result, electrons flow readily from the emitter to the base, where some of them combine with the holes in the P-type crystal. If this crystal were made thin enough, nearly all the electrons entering the emitter would be attracted to the positive collector terminal and flow through the external collector circuit to battery B. That is, a flow of current in the emitter circuit produces almost the same flow of current in the collector circuit. However, since the impedance (Z) of the emitter circuit is low and that of the collector circuit is high, the power ($I^2 \times Z$) is greater in the collector circuit than in the emitter circuit. This explains how the junction transistor acts as a power amplifier—a device that increases the input signal without changing its characteristics a great deal. To indicate the obtainable increase in power, or gain (Ic), the impedance of the emitter circuit may be as low as 25 ohms, whereas the impedance of the collector circuit may be several megohms.



73.375
Figure 15-17.—Basic junction transistor circuit.

The basic amplifying circuit is shown in figure 15-18. Assume that the incoming signal is in the form of an alternating voltage. When connected into the emitter circuit, the signal source alternately adds to or subtracts from the voltage of battery A. Hence, the current flow through the low-impedance emitter circuit is respectively larger or smaller. Accordingly, a larger or smaller current flows through the high-impedance collector circuit (which contains the load in series). As explained previously, a low power input to the emitter circuit produces a large power output at the load in the collector circuit. The transistor is called an N-P-N junction transistor because of the arrangement of the N- and P-type crystals.

It is possible to form a P-N-P junction transistor by sandwiching the N-type crystal between two P-type crystals. Since the relative



73.376
Figure 15-18.—N-P-N junction transistor used as amplifier.

positions of the crystals are reversed in the P-N-P transistor, the polarities of the battery must be reversed; also, instead of electrons, holes flow from the emitter to the negatively charged collector terminal. Figure 15-19 shows the differences in the schematic symbols for the N-P-N and P-N-P transistors.

Transistors can carry out many of the functions of electron tubes. Transistors have certain advantages in that they consume less power, last longer, can take rough handling, and can be built much smaller and more compactly. Also, transistors have no filaments, so practically no heat is produced.

TRANSISTOR LEAD IDENTIFICATION

You must be able to identify the leads or terminals of a transistor before it is connected into a circuit. As there is no standard method of identifying transistor leads or terminals, it is quite possible to mistake one lead for another.

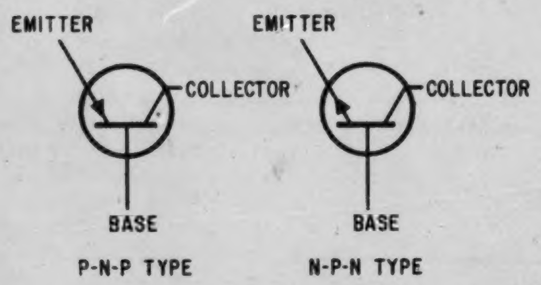


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Figure 15-19.—Schematic diagrams of transistor types.

In figure 15-20, the bases of four pairs of transistors are shown. Each pair, while similar in appearance, has different elements connected to the leads. For the top transistor of the left-hand pair, the leads are emitter, base, collector, reading from left to right; for the bottom transistor of this pair, the leads are emitter, collector, and base. If one of these transistors was connected into a circuit as a replacement for the other, the circuit would not function properly or the transistor might be destroyed. The same general results apply for the other pairs of transistors. Note that in the right-hand pair, the cases can and are used for emitter or collector connections.

In replacing one transistor with another, do not rely on shape. Be sure the leads are where they should be and that the transistor chosen as a replacement is suitable. If there is any doubt, consult the equipment manual or a transistor manual showing the specifications for the transistor being used.

CIRCUITRY

There are three basic ways of connecting a transistor in a circuit: common or grounded base (fig. 15-21), common or grounded emitter (fig 15-22), and common or grounded collector (fig 15-23). The connections differ in whether the base, emitter, or collector is part of (common to) both the emitter and collector circuits. Regardless of the connection, the output signal is taken from across the load.

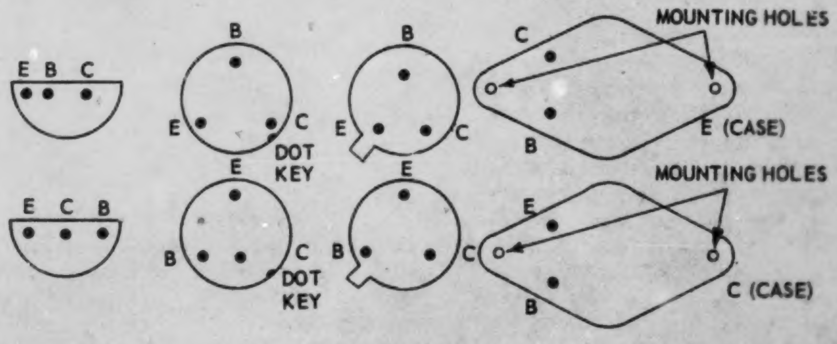

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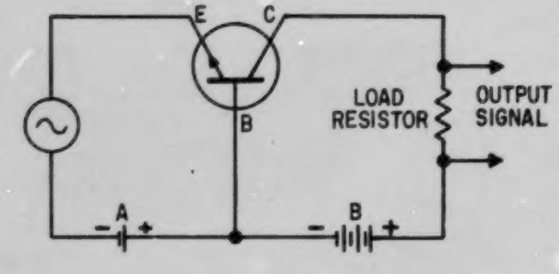
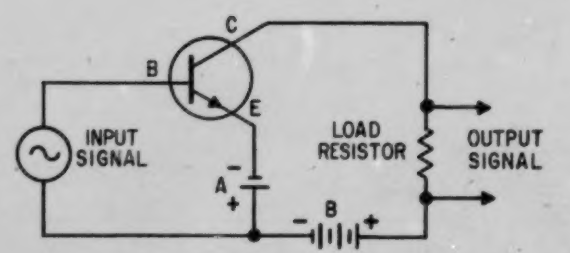
Figure 15-20.—Bottom view of some common transistor cases.



73.378
Figure 15-21.—Common base amplifier circuit.



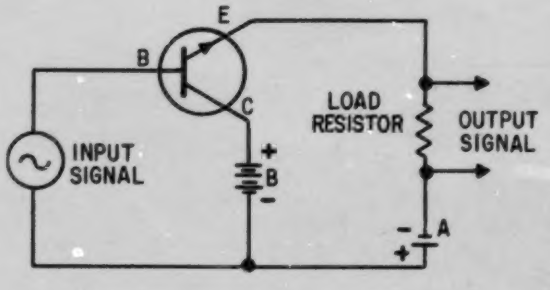
73.379
Figure 15-22.—Common emitter amplifier circuit.

Note that the symbols indicate the use of an N-P-N transistor in each circuit. With a P-N-P transistor, reverse the polarities of the battery. Each basic circuit has its own measureable properties, such as impedance or gain under given operating conditions. Which circuit is to be used depends upon the design requirements of a particular amplifier.

Table 15-2 compares characteristics of the three basic circuits.

ELECTRON TUBE TRIODES

Another kind of electron tube, the triode, is widely used as an amplifier of signals. As its name suggests, the triode has three elements: cathode, plate, and control grid. This grid is usually a metal screen or coil of fine wire inserted between the plate and cathode, but closer to the cathode. As long as the grid is uncharged, most of the electrons flowing from the cathode to the plate are free to move through the openings of the grid. Placing a negative charge on the grid has a repelling effect on the stream of electrons



73.380
Figure 15-23.—Common collector amplifier circuit.

Table 15-2.—Transistor amplifier comparison chart

AMPLIFIER TYPE	COMMON BASE	COMMON EMITTER	COMMON COLLECTOR
INPUT/OUTPUT PHASE RELATIONSHIP	0°	180°	0°
VOLTAGE GAIN	HIGH	MEDIUM	LOW
CURRENT GAIN	LOW (α)	MEDIUM(β)	HIGH (γ)
POWER GAIN	LOW	HIGH	MEDIUM
INPUT IMPEDANCE	LOW	MEDIUM	HIGH
OUTPUT IMPEDANCE	HIGH	MEDIUM	LOW

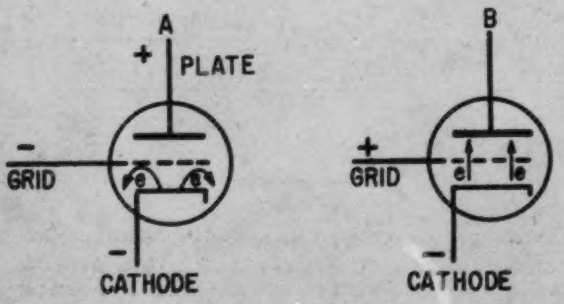
179.94

passing through the grid, and tends to reduce the number of electrons that do. Increase the negative charge, and fewer electrons pass through the grid. When the negative charge on the grid is made large enough, electrons do not pass between the cathode and plate (fig. 15-24, view A.)

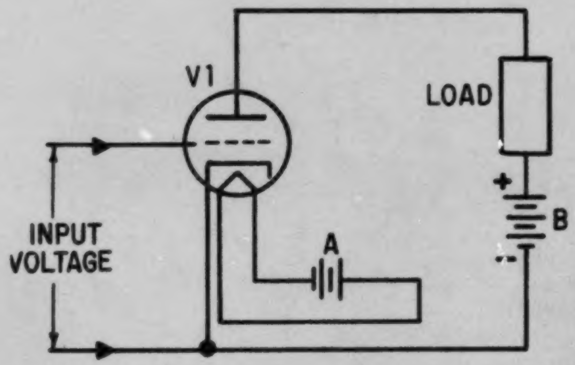
However, a positive charge placed on the grid attracts the electrons. Increase the positive charge, and more electrons are attracted to the grid. Some electrons strike the wire of the grid, but most of them flow through to strike the plate (fig. 15-24, view B) since the grid is mainly open space. The grid, then, regulates the flow of electrons much as a venetian blind controls the amount of light that enters a room. Depending on the voltage applied to the grid, more or less plate current flows through it.

Of course, you can vary the plate current flow by making the plate more or less positive. But since the grid is closer to the cathode (the source of electrons), a smaller variation in the charge of the grid has the same effect on the plate current as a larger variation on the charge of the plate. Weak signals change the charge and voltage on the grid, and so produce big changes in the plate current. In this way, the triode amplifies the weak signals.

The triode of figure 15-25 has three distinct circuits: the FILAMENT circuit consisting of the heater and A battery or other source of heating current; the PLATE, or output, circuit consisting of the cathode, the electron flow from cathode to plate within the tube, the plate, the load, and the B battery (commonly known as B+); and the GRID, or input, circuit consisting of the cathode control grid, and the source of input voltage.



73.381
Figure 15-24.—Effect of the grid in a triode.



73.382
Figure 15-25.—Basic triode circuits.

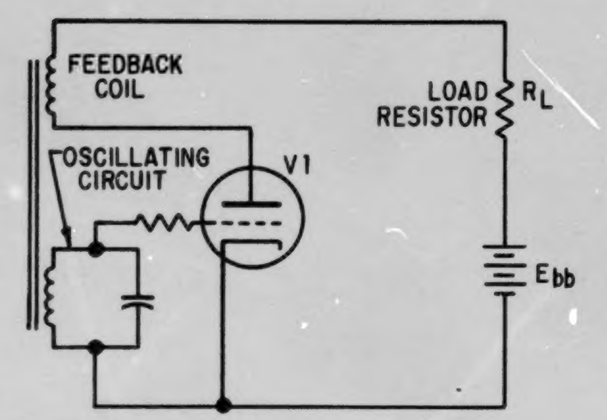
To demonstrate the use of a triode as an amplifier, assume that a small varying voltage is applied to the grid circuit. Since the charge on the grid varies with the applied voltage, the plate current flowing through the tube varies accordingly, causing similar variations in the current flowing through the load. If the load resistance is high, the resulting voltage drop (I x R) across the load is also high and varies directly with the input voltage. Therefore, a small varying voltage applied to the input circuit of the triode produces a large varying voltage in the output circuit.

The triode can be compared to the transistor, The cathode operates like the emitter, the plate like the collector, and the grid like the base.

OSCILLATORS

An amplifier, such as the triode, can also be used as an oscillator—an electronic device that produces a constant signal of a certain frequency. As an oscillator, the triode feeds back to itself part of the signal it puts out. The feedback produces signals that oscillate, or vibrate, at a certain frequency. The resistance inductance, and capacitance of the input circuit enable the triode to amplify only the signals that have the desired frequency. This is commonly known as the resonant frequency.

To demonstrate the use of a triode as an oscillator, connect the input circuit of the tube as shown in figure 15-26. This places an a-c voltage on the grid of the triode. The resulting plate current satisfies the needs of the load



73.383
Figure 15-26.—Oscillator, triode, and feedback circuit.

with enough left over to feed back to the oscillating circuit to compensate for its losses, and to remain in oscillation. The plate current feeds back through the so-called feedback coil that is coupled (connected) to the inductor of the oscillating circuit. In this way the feedback coil serves as the primary winding of a transformer; the inductor of the oscillating circuit as the secondary winding.

When proper values are selected for the inductor and the capacitor of an oscillating circuit, frequencies in millions, even billions, of hertz (cycles per second) can be generated.

Example: Assume that the value of an inductor is 20 microhenrys and that of a capacitor is 80 picofarads. Determine the frequency by using the formula:

$$\text{Frequency} = \frac{1}{2\pi \sqrt{L \times C}}$$

where $L = 20\ \mu h = 2 \times 10^{-5}$ henrys and $C = 80\ pF = 8 \times 10^{-11}$ farads

$$\text{Frequency} = \frac{1}{2\pi\sqrt{2 \times 10^{-5} \times 8 \times 10^{-11}}}$$

$$= \frac{1}{2\pi\sqrt{16 \times 10^{-16}}} = \frac{1}{2\pi \times 4 \times 10^{-8}}$$

$$= \frac{10^8}{8\pi} = 4{,}000{,}000 \text{ Hz (approximately)}$$

MULTIELEMENT ELECTRON TUBES

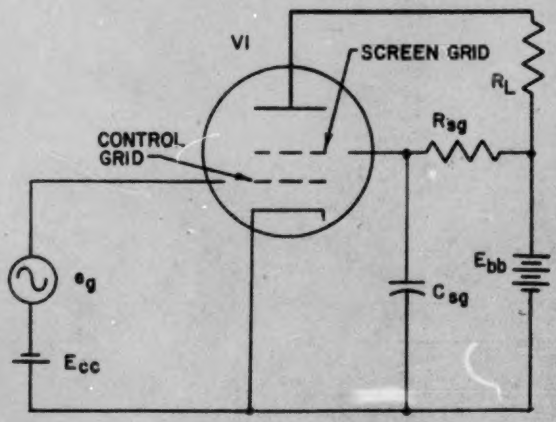
Several elements other than the cathode, plate, and control grid are inserted in some electron tubes for special purposes. Tubes having more than these three elements are known as multielement tubes. A tetrode, for example, is a four-element tube. Its extra element is another grid called the screen grid. Another electron tube, the pentode, has three grids—a control grid, a screen grid, and a suppressor grid. All multielement tubes have special uses and some require special tube sockets. All of them, however, work on the same basic principle as the triode.

TETRODES

The tetrode is an amplifying tube. Its fourth element, the screen grid, is mounted between the control grid and the plate. (See figure 15-27.) The screen grid has a positive charge with respect to the cathode; it attracts a steady flow of electrons from the cathode. Because the mesh of the screen grid is relatively large, most of the attracted electrons pass through it and, in turn, are attracted by the plate. Thus the screen grid supplies an electrostatic force that pulls electrons from the cathode to the plate.

As long as the plate voltage is higher than the effective screen grid-to-cathode voltage, plate current in a tetrode depends mostly on screen-grid voltage and little on plate voltage. Thus a tetrode is better as an amplifier than a triode. Also, the screen grid reduces capacitance by serving as an electrostatic shield between the control grid and the plate. Reducing grid-to-plate capacitance results in high amplification and keeps the amplifier from oscillating.

Figure 15-27 illustrates a basic tetrode amplifier circuit. R_{sg} is the screen-dropping resistor



73.384
Figure 15-27.—Basic tetrode amplifier circuit.

that maintains the screen-grid operating voltage; C_{sg} is the screen-bypass capacitor that maintains the screen grid at a constant voltage.

PENTODES

The pentode's fifth element, or suppressor grid, is located between the screen grid and the plate. The suppressor grid is connected internally or externally to the cathode. Figure 15-28 shows the internal connection.

Electrons flowing from the cathode to the plate cause the plate to give off electrons by secondary emission, which means freeing of electrons by bombarding them with other electrons. Being negative with respect to the plate, the suppressor grid keeps the secondary emission electrons from leaving the plate and interfering with the operation of the tube. The main electron stream is hardly affected by the presence of the suppressor grid.

Since the suppressor grid is negative with respect to the screen grid or plate, it does not draw current. Therefore the relationships of voltages and currents are essentially the same as those in the tetrode.

The pentode has replaced the tetrode in radio frequency (RF) amplifiers because it permits a somewhat higher amplification in moderate values of plate potential. In some special-purpose pentodes, the suppressor grid serves as a signal grid.

METHODS OF BIASING

In some amplifier circuits, d-c voltage in the grid circuit is supplied from a fixed source, such as a battery or other power supply (fig. 15-29). This type of voltage is known as fixed bias. In another type, called self-bias, voltage is developed across a resistor by tube current or input signal. Cathode bias and grid-leak bias are forms of self-bias.

CATHODE BIAS

This form of self-bias is illustrated in figure 15-30. When the cathode of an electron tube is biased positively with respect to the grid, the electron tube operates exactly as though an equivalent negative bias is applied to the grid. Since current flow with an electron tube is from the cathode to the plate, a resistor can be inserted in the cathode line to procuce a voltage drop (cathode bias) as long as the plate current flows continuously. Since cathode current always flows in the same direction, the voltage drop remains more positive at the cathode. Thus, plate current flow within the electron tube itself produces a positive cathode bias.

GRID-LEAK BIAS

Grid-leak bias is obtained by allowing grid current flow, produced by an a-c signal input, to charge a resistance-capacitance (RC) network in the grid-cathode circuit. Two basic circuits

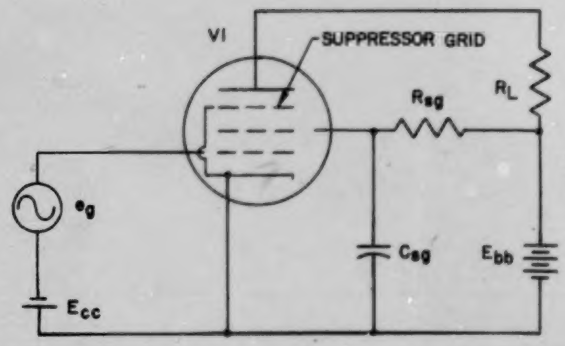


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Figure 15-28.—Basic pentode amplifier circuit.

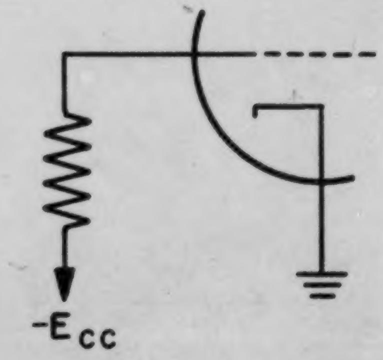

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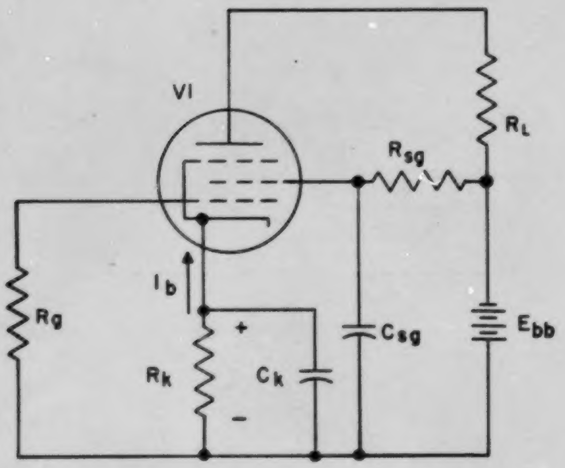
Figure 15-29.—Schematic of fixed bias.



73.387

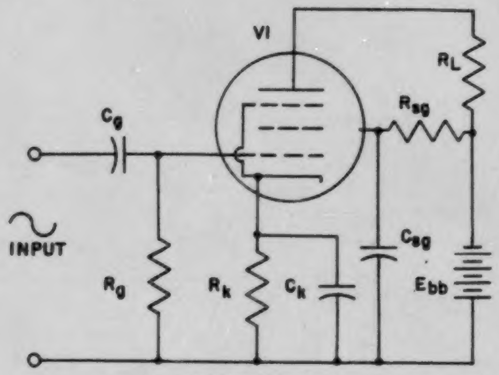
Figure 15-30.—Obtaining cathode bias.

are used to develop this form of self-bias: shunt and series (fig. 15-31). The methods of developing grid voltage in these circuits are similar, but the physical connections of the network components are different.

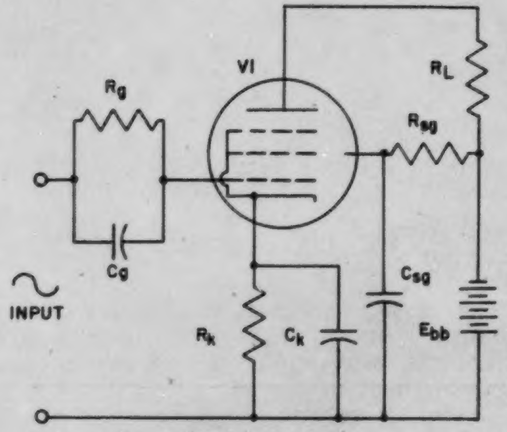
The grid-cathode circuit is used in both basic circuits as a diode rectifier to develop a d-c voltage proportional to the positive peak input (driving) signal amplitude. A grid-leak capacitor (Ck) operates as a coupling capacitor to apply the input signal to the grid. On the positive input signal excursions, the grid is driven positive, causing grid current to flow between grid and cathode and through a grid-leak resistor (Rg). The result is to produce a d-c voltage across Rg which is polarized negatively at the grid.

COUPLING METHODS

Usually more than one amplifier is needed to increase the amplitude of a feeble input signal to the required output valve. The amplifiers are cascaded, that is, connected in series so the output of one goes to the input of another. Cascaded amplifier stages are connected (coupled) by resistance-capacitance (RC) networks, impedance (LCR) networks, transformers, or direct coupling. Though some coupling networks respond to frequency better than others, the basic method of coupling is the same whether the amplifiers are used singly (as input or output coupling devices) or in cascade.



A.- SHUNT TYPE



B.- SERIES TYPE

73.388

Figure 15-31.—Grid-leak bias connections.

RC COUPLING

RC coupling involves the use of two resistors and a capacitor, as shown in figure 15-32. Because of their rather high frequency response, small size, and economy of operation, RC-coupled amplifiers are nearly always used where voltage amplification is desired with little or no power output. Since the plate resistor (R_L) and grid resistor (Rg) are not frequency responsive, the overall frequency response is limited basically by the capacitive reactance of the coupling capacitor (C_C) between the plate and grid circuits, plus the effect of shunt wiring and cathode-to-ground capacitances across the network. With

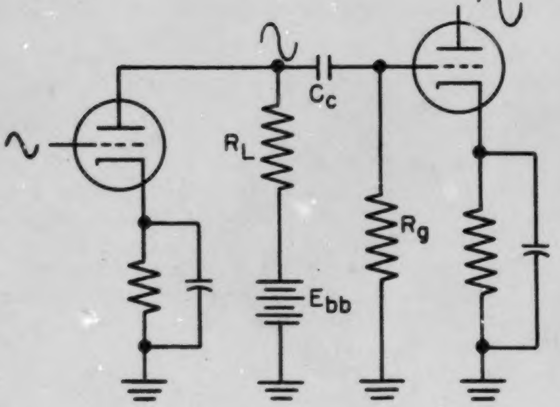


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Figure 15-32.—RC-coupled amplifier.

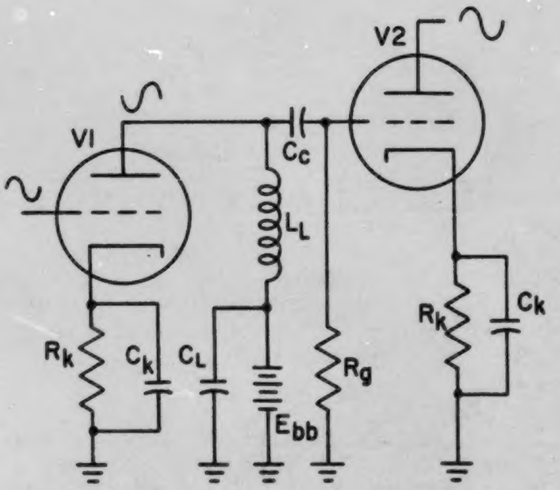

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Figure 15-33.—Impedance-coupled amplifier.

direct current (zero frequency) the coupling capacitor separates or blocks the plate voltage of the driving stage from the grid bias of the driven stage, so that bias or plate or element voltages are not affected between stages. Note that, with respect to alternating current, the tubes are in parallel with R_L.

In the conventional RC amplifier, signal voltage variations on the grid produce plate current variations through the plate resistor, and the resulting voltage developed across it represents an amplified replica of the input signal but 180 degrees out of phase. The amplified signal is coupled through capacitor C_c and applied to the grid of the next stage across the grid resistor. The same cycle of operation is repeated for each stage of the cascaded amplifier.

RC-coupled amplifiers generally have a low gain, or ratio of signal output to signal input; therefore, they are seldom used in RF amplifiers. They have special applications, such as test equipment.

IMPEDANCE COUPLING

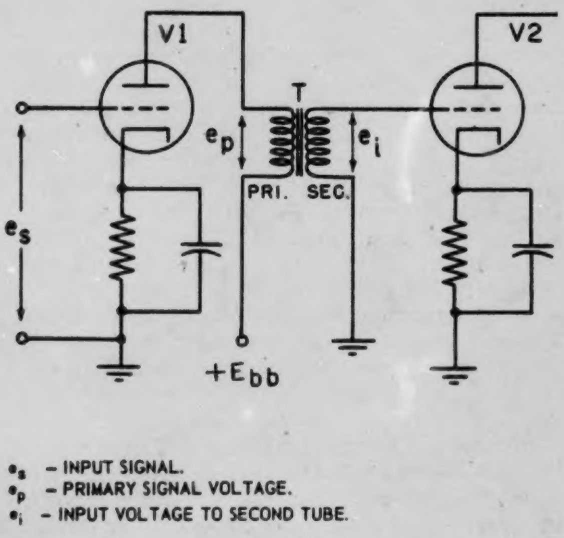
When an inductor is substituted for the plate load resistor in an RC-coupled circuit, an impedance-coupled circuit results (fig. 5-33). The impedance coupled and RC-coupled circuits operate in the same manner as far as C_c and Rg are concerned; the basic difference lies in the effect of plate impedance. By using an impedance in the plate circuit, there is a smaller voltage drop for a given voltage supply. Therefore, a lower supply source will provide the same effective plate voltage, smaller loss in power (I^2R), and better overall efficiency. Low frequency response depends on obtaining a high inductive reactance in the plate circuit and requires a large number of turns for good low-frequency response. The distributed capacitance associated with a winding of many turns produces a large shunting capacitive reactance with a consequent drop in high-frequency response. Since the impedance of the plate circuit varies with frequency, the response is not as uniform as that of the RC coupling.

The impedance-coupling circuit is used where a limited response over a relatively narrow band of frequencies is required. As a result, impedance coupling is usually found in amplifier stages, such as intermediate-frequency or radio-frequency stages. Its use in audio frequency stages has generally been discontinued in favor of the RC or transformer coupling, except for special designs.

TRANSFORMER COUPLING

In transformer coupling (fig. 15-34), the primary of a transformer is connected as the plate load, and the secondary provides the output signal, either to the next stage or an output device. Frequency response, gain, and output become more difficult to predict because they depend primarily on the transformer design. Basically, transformer coupling provides additional gain, through the use of a step-up turns ratio of primary to secondary, but this gain usually does not exceed 2 or 3 to 1. Since there is no physical d-c connection between stages, plate and bias voltages are kept separate, and the a-c signal is coupled from the plate of one stage to the grid of the following stage by mutual inductive coupling between primary and secondary windings.

Transformer coupling is generally used for interstage applications with electron tubes having plate resistances of 5 to 10 thousand ohms maximum, since higher plate resistances require excessively larger transformer primary inductances. For output stages, lower plate resistances are used, and the transformer is carefully designed to handle larger plate currents. Generally speaking, a lower plate current produces fewer d-c core saturation effects.


V1
V2
T
e_p
e_i
PRI.
SEC.
e_s
$+E_{bb}$
e_s – INPUT SIGNAL.
e_p – PRIMARY SIGNAL VOLTAGE.
e_i – INPUT VOLTAGE TO SECOND TUBE.

20.97

Figure 15-34.—Transformer-coupled voltage amplifier.

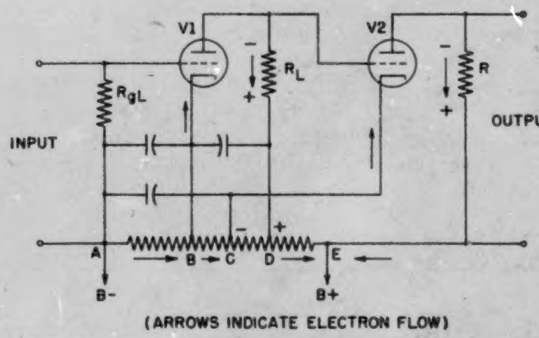
Since the impedance transformation in a transformer varies as the square of the turns ratio between primary and secondary, output and input matching is possible and is a common practice. For interstage applications, matching is not always used, because power output is not required; in these cases, more attention is given to the step-up ratio to provide a higher voltage gain.

The limitations of frequency response generally restrict the use of transformer coupling to audio circuits which do not require an exceptionally wide bandpass or frequency response, but do require voltage or power outputs.

DIRECT COUPLING

In a direct-coupled amplifier (fig. 15-35), the plate of the driver stage is connected to the grid of the driven stage, and the coupling network is eliminated. Since the plate and bias circuits are not isolated by a transformer or coupling capacitor, the direct-coupling circuitry is slightly complicated by the arrangement necessary to produce an effective negative bias.

Because a coupling network is not inserted between the output of one tube and the input of the following tube, there is no phase distortion, time delay, or loss of frequency response. Since the plate and grid of the tubes are directly connected, the low-frequency response is extended to direct current (zero frequency). The high-frequency response is limited only by the tube interelectrode-to-ground capacitance, plus the



20.102

Figure 15-35.—Direct-coupled amplifier.

circuit distributed wiring capacitance. By appropriate matching (or mismatching) of tubes, high values of amplification and power output may be obtained.

Since the use of more than two stages requires plate voltages two or more times the normal value for one tube, plate supply considerations limit direct coupling to a few stages. Any change in the supply voltage affects the bias of all the tubes and is cumulative; therefore, special voltage supply regulation circuits are necessary. Noise and thermal effects in tubes produce circuit instability and drift that limit the use of this type of coupling in audio or RF amplifiers.

Because of its ability to amplify direct current (zero frequency), direct-coupled circuitry is often used in computer circuits, and in the output circuits of video amplifiers. It is also used in pulse circuits because response is practically instantaneous.

BASE LEAD CURRENT

The amount of transistor current depends on several variables, such as type of bias, (fixed bias, self-bias), magnitude of the input signal, basic transistor connection, type of transistor, and direction of current flow in the base lead. For example, if the base lead current is flowing into the base material in the P-N-P (fig. 15-36, view A), or out of the base material into the base lead in an N-P-N, as in view B, more current is flowing in the emitter. If the reverse is true, as shown in views C and D, then more current is flowing in the collector.

The transistor amplifiers described earlier were biased in forward and reverse directions through the use of two batteries. The purpose for using two batteries was to simplify the explanation of transistor operation. In actual practice, two batteries are seldom used. Single source biasing will point out the necessity for knowing in which direction base lead current is normally flowing.

SINGLE SOURCE BIASING

Single source biasing has the advantage of using the existing power supply to satisfy the needs for transistor biasing. This not only eliminates the need for a separate power supply, but also simplifies circuit wiring. The main reason for simplification is that both the collector and the base require voltages, which possess the same polarity with respect to the emitter, for biasing purposes.

A transistor with its three doped elements may be simplified to three resistances in series with each other. Figure 15-37, view A, shows the schematic diagram of an N-P-N transistor. Its three elements can be broken down into their equivalent electrical representation shown in view B. Now, by application of a negative source to the emitter material, that point is made the most negative in the branch, while the collector material is the least negative. In view C, point B is less negative than point A, or positive with respect to point A. In effect, the base is made positive with respect to the

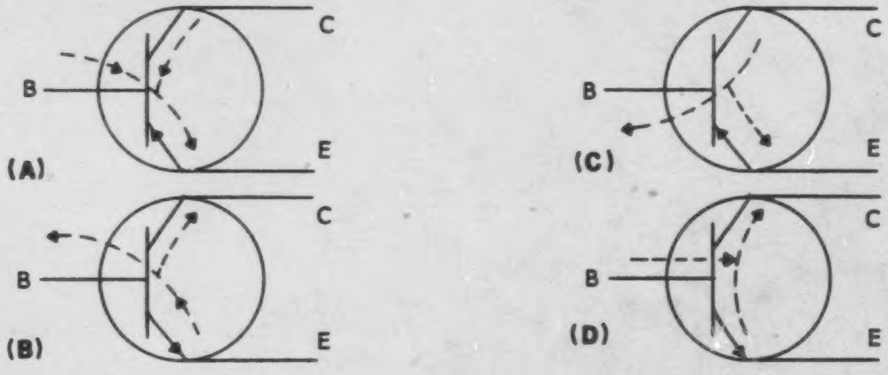


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Figure 15-36.—Base lead current flowing into, or out of, the base material in N-P-N and P-N-P transistors.

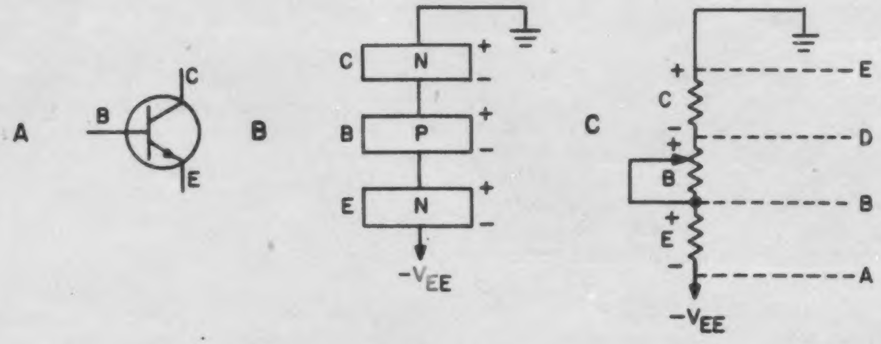

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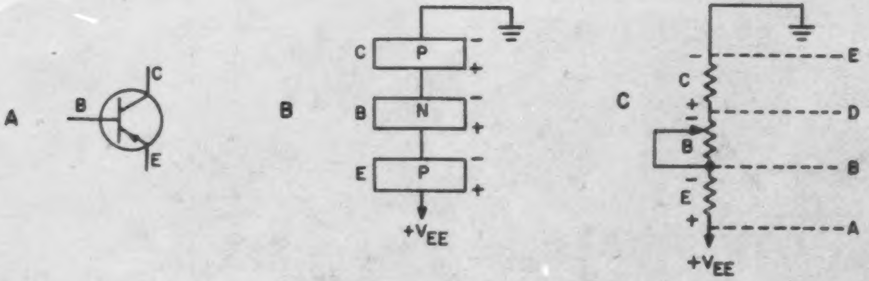
Figure 15-37.—Schematic diagram of an N-P-N transistor broken down to equivalent electrical representation and resistance equivalent.

emitter, and the requirements for forward bias in an N-P-N transistor are met.

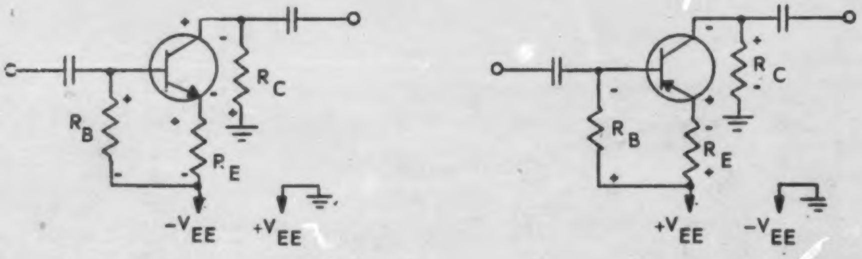
The base material, being situated between the collector and the emitter, will always find itself electrically at some potential between the collector and the emitter. Also, the base is represented in view C of figure 15-37 as a variable resistance to show that an increase in forward bias should decrease this resistance. When the arm moves from point B to point D, the total resistance in the circuit is effectively decreased, flow from point D is at the same potential as point B with respect to point A, giving more forward bias; and more current is allowed to flow from the collector to the emitter. When the arm is moved back to point B, the total resistance is increased, decreasing the current flow in the circuit; now point B is less positive than point D with respect to point A, resulting in less forward bias.

Figure 15-38 illustrates the P-N-P, again three equivalent resistances are used and this time a positive source is applied to the emitter source terminal. It may be noted that point A is the most positive point in the network and that point B is less positive than point A, while point D is less positive than (negative with respect to) point B. In this P-N-P, the bias is negative with respect to the emitter, which satisfies the forward bias requirement for this type of transistor. Once more, the base is



179.105

Figure 15-38.—Schematic diagram of a P-N-P transistor broken down to equivalent electrical representation and resistance equivalent.



179.106

Figure 15-39.—Establishing transistor polarities.

shown as a variable resistance to illustrate that forward bias can be increased or decreased.

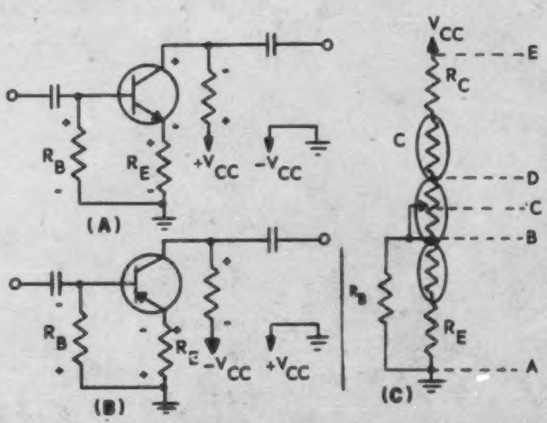
The addition of a single resistor from the base to the emitter source terminal simply shunts the base-emitter junction, further decreasing its resistance, permitting more forward bias to be applied. Should the base current flow increase and, consequently, the transistor current flow, with no signal input, you should check the value of R_B; an open base resistor would allow a greater difference of potential to be felt between the base and the emitter and therefore more current through the transistor. The base-emitter resistor reduces the resistance of the base-emitter junction, reducing the amount of forward bias with no signal applied. A direct short circuit from the base to the emitter would of course cause all signal to be lost and an excessive amount of current flow through the device. By considering the transistor as being three resistances in series, you can always establish the polarity of any given material in respect to an adjacent material, regardless of the polarity of the source, as shown in figure 15-39.

The N-P-N transistor may have its collector connected to a positive source as shown in figure 15-40, view A. In this case, point E in view C is positive in respect to point D, point D is positive in respect to point C, and point C is positive with respect to point B. The base is positive with respect to the emitter, and, therefore, it is forward biased. Where a P-N-P transistor has a negative source on its collector, (fig. 15-40, view B), point E in view C is negative with respect to point D, point D is negative with respect to point C, and point C is negative with respect to point B. The base is thus negative with respect to the emitter and in a P-N-P this is forward bias. In both cases R_B is shunting the base to emitter junction.

TESTING ELECTRON TUBES

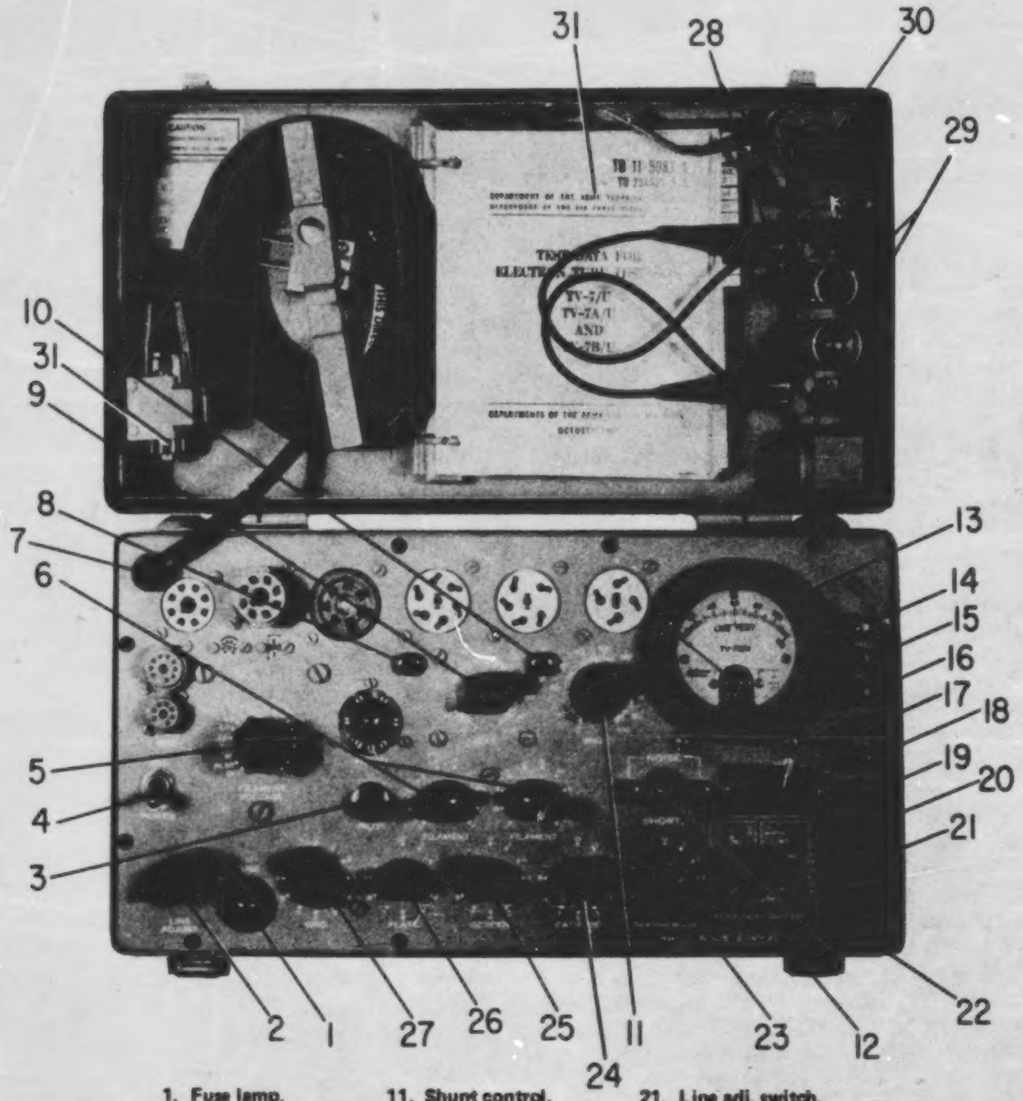
There are two types of equipment in general use for testing electron tubes: emission and transconductance testers. The emission tester indicates the ability of a tube to emit electrons from its cathode. Transconductance testers not only indicate this ability of an electron tube but also the ability of its grid voltage to control plate current. The TV-7/U tube tester is a typical transconductance-type of tester (fig. 15-41). With the front panel controls of this tester, you adjust (or switch) the various potentials necessary for testing tubes. The tube data chart that is supplied with the tester lists the control settings for the most common types of tubes.

Before inserting a tube in the correct test socket, make certain that the front panel controls are set to the positions listed in the data



179.107

Figure 15-40.—N-P-N and P-N-P transistor equivalent circuit.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TV-7/U
TV-7A/U
AND

1. Fuse lamp.
2. Line adj. control.
3. Pilot light.
4. Power switch.
5. Filament voltage.
6. Filament selectors.
7. A-c line cords.
8. Grid jack.
9. Bias control.
10. Plate jack.
11. Shunt control.
12. Neon lamp.
13. Meter.
14. Meter reverse switch.
15. Rectifier switch.
16. OZ4 switch.
17. Gas 2 switch.
18. Gas 1 switch.
19. Mut. Cond. switch.
20. Diode switch.
21. Line adj. switch.
22. Function switch.
23. Suppressor selector.
24. Cathode selector.
25. Screen selector.
26. Plate selector.
27. Grid selector.
28. Test leads.
29. Pin straighteners.
30. Adapter.
31. Test data book.

243.379

Figure 15-41.—Electron Tube Test Set, TV-7/U

chart for that tube. This precaution is necessary to prevent excessive voltage from being applied to the tube elements (especially the filament).

LINE VOLTAGE ADJUSTMENT AND TEST

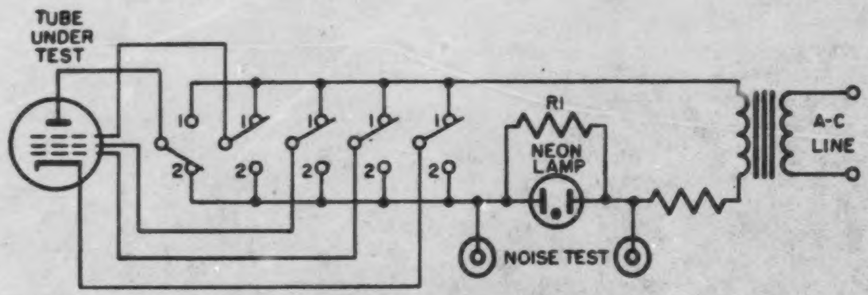
The line voltage adjustment is necessary so that the line voltage applied to the primary of the transformer can be present to an operating value. A 93-volt potential is used as a test reference point, regardless of the variations caused by different tube loads or fluctuations in the a-c supply. Applied voltages may range from 105 to 130 volts and still be adjustable. Depressing the LINE TEST button connects the meter of the tube tester to read the "B" supply voltage. The test equipment is calibrated at the factory so that the meter pointer is approximately centered when the voltage across the primary is 93 volts. Since various types of electron tubes draw different values of currents, a LINE ADJUSTMENT rheostat (connected in series with the primary) is provided. The primary voltage can thus be set to the designed operating voltage before any test is begun. A small protective lamp which will burn out on overload is connected in series with the primary of the transformer to prevent equipment damage.

SHORT CIRCUIT AND NOISE TEST

It is very important that the technician apply the test for short-circuited elements to a tube of doubtful quality before any other tests are made. This procedure protects the meter (or any other indicator) from damage. Also it follows logically that, if a tube under test has elements which are short-circuited, there is no further need to apply additional tests to that tube. Short-circuit tests are usually sensitive enough to indicate leakage resistance less than about one-fourth megohm. The proper heater voltage is applied so that any tube elements which might short as a result of the heating process will be detected. The short-circuit test is similar to the test used to detect noisy (microphonic) tubes caused by loose elements. Since the only difference between the two tests is in the sensitivity of the device used as an indicator, the noise test is discussed as part of the short-circuit test.

Figure 15-42 shows a basic circuit used for detecting shorted elements within a tube. With the switch set to position 2 as shown, the plate of the tube under test is connected to the leg of the transformer secondary containing the neon lamp. All the other elements are connected through switches to the other leg of the secondary. If the plate element of the tube is touching any other element within the tube, the a-c circuit of the secondary is completed and as a result, both plates of the neon lamp glow. If no short exists, only one plate of the neon lamp will glow. Each of the other elements is tested by means of the switching arrangement shown. Resistor R2 limits the current through the neon lamp to a safe value. Resistor R1 bypasses any small alternating currents in the circuit which might be caused by stray capacitance and thus prevents the neon lamp from indicating erroneously. Tapping the tube lightly is recommended to detect loose elements which might touch when the tube is vibrated.

The circuit used to test for shorts is similar to the basic circuit of figure 15-42. By means of



1.75

Figure 15-42.—Basic circuit used for short circuit and noise test.

the function switch the electrodes of the tube under test are switched in turn across a neon SHORTS lamp, which is connected in series with the secondary of the transformer. Shorted tube elements (and any other internal tube connections) complete the a-c circuit, causing both plates of the neon lamp to glow. Momentary flashes of the neon SHORTS lamp may be caused when the switch is rotated. These flashes are caused by the charging of the small interelectrode capacitances of the tube when the voltage is applied, and do not indicate short circuits. If the tube under test has a shorted element, the neon lamp will glow continually on one or more switch positions. Since the filament circuit and other internal tube connections will show up as short circuits in this test, the tube data chart should be consulted for pin connection information before interpreting the results of the test.

The noise test is used to check for intermittent shorts or microphonic noise. The circuit used is the same as that employed for the short-circuit test. In tests for noise, the antenna and ground terminals of a radio receiver are connected to the NOISE TEST receptacles. Any intermittent short between tube electrodes permits the a-c voltage from the power transformer to be applied momentarily to the neon lamp.

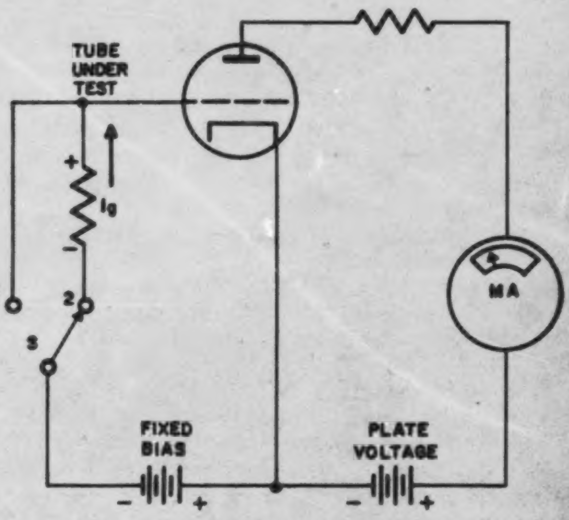
The brief oscillation of this lamp contains various radiofrequencies which are reproduced as audible signals in the receiver speaker. A less sensitive noise test can be made using a pair of headphones instead of the radio receiver. The tube should be tapped while it is being tested.

GAS TEST

In all electron tubes, except some types of rectifier tubes and thyratrons, the presence of any appreciable amount of gas is extremely undesirable. When gas is present, the electrons emitted by the cathode collide with the molecules of gas. As a result of these collisions, electrons (secondarily emitted) are dislodged from the gas molecules, and positive gas ions are formed. These ions are attracted by (and cluster around) the control grid of the tube, absorbing electrons from the grid circuit in order to revert to the more stable gas molecules (not ionized). If the amount of gas in the tube is appreciable, the collisions between the numerous gas molecules and the cathode-emitted electrons release many secondarily emitted electrons, and the resulting flow of grid current is high.

The basic circuit used for the gas test is shown in figure 15-43. With switch S set to position 1, a certain value of plate current is measured by the d-c milliammeter. If there is no gas (or a negligible amount) present in the tube, setting switch S to position 2 does not change the plate-current reading. If gas is present, current flows through the grid resistor (large value), causing a voltage drop to develop with the polarity as shown. The net effect is to reduce the negative bias voltage on the grid of the tube resulting in an increase of plate current. Small plate current increases are normal; large increases indicate excessive gas.

The value of the grid resistor used in the typical tube tester is 180,000 ohms. Two pushbutton switches, labeled GAS No. 1 and GAS No. 2, are used for gas test. GAS No. 1 button is first depressed and the plate current reading on the meter is noted. Depressing the button marked GAS No. 2 inserts the 180,000-ohm resistor into the grid circuit. If gas is present in the tube, the grid current that flows reduces the normal bias on the tube and increases the plate current measured by the meter. A tube with a negligible amount of gas produces an increase in plate current of less than one scale division when GAS No. 2 button is depressed. An increase of more than one scale division indicates an excessive amount of gas in the tube.



1.76

Figure 15-43.—Basic circuit used for gas test.

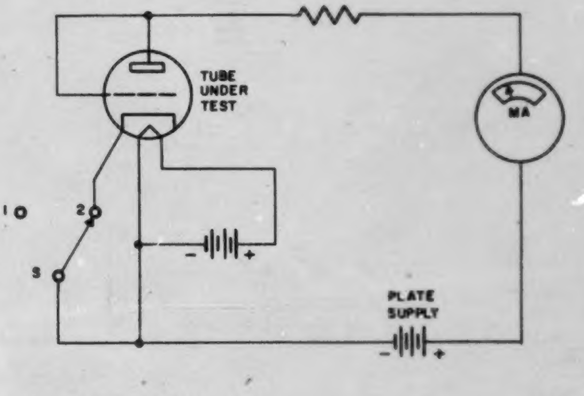
CATHODE LEAKAGE TEST

When a tube which uses an indirectly heated cathode develops noise, it is almost a certain indication that a leakage path is present between the cathode sleeve and the heater wire. This assumption is justified because in the design of a tube the heater must be placed as close as possible to the cathode so that maximum tube efficiency is attained. Continual heating and cooling of the tube structure may cause small amounts of the insulation between the cathode and heater to become brittle or deteriorate, leaving a high resistance leakage path between these elements. Under extreme conditions the insulation may shift enough to allow actual contact of the elements. Since the heater and cathode are seldom at the same potential, any form of leakage causes noise to develop in the tube.

The cathode normally is maintained at a higher positive potential, because cathode bias is the most common type of bias utilized. The heater circuit is usually grounded to chassis, either on one side of the filament supply or by a center-tap arrangement. Therefore, if a resistance path is present, a leakage current may flow from the heater to the cathode. Thus, in effect, the cathode functions in the same manner as the plate of a tube; that is, it receives electrons. Assuming the existence of a high-resistance short, the current flow from the heater to the cathode will vary with any vibration of the tube because vibration varies the amount of resistance. If the cathode and heater are completely shorted (zero ohms), it is impossible for the tube to develop any cathode bias.

A cathode leakage test is sometimes made while a tube is being tested for short-circuited elements or noise. However, some tube-testing instruments incorporate the cathode leakage test as an additional test which is not part of the short-circuit test. Figure 15-44 shows a basic circuit which is used to detect leakage between the heater and cathode elements of a tube. With switch S set to position 2, a certain value of plate current flows.

When switch S is set to position 1, the cathode becomes a floating element; if no leakage path is present, the plate current should fall to zero. If the elements are completely shorted, the plate current reading remains the same as the initial reading (switch S in position 2); if they are only partially shorted, a plate current less than normal but greater than zero is indicated.



1.77

Figure 15-44.—Basic circuit used for cathode leakage test.

FILAMENT ACTIVITY TEST

The filament activity test is used to determine the approximate remaining life of an electron tube insofar as the longevity of the cathode emitter is concerned. The test is based on the principle that the cathode in almost all electron tubes is so constructed that a decrease of 10 percent of the rated heater voltage causes no appreciable decrease in emission.

On tube-testing equipment incorporating this test, there is a two-position switch (FILAMENT ACTIVITY TEST) which has one position marked NORMAL and the other marked TEST. The switch remains in the NORMAL position for all tests other than the filament activity test. When the switch is set to the TEST position, the filament (or heater) voltage which is applied to the tube under test is reduced by 10 percent.

The filament activity test is performed as follows: After the quality test is made, the TUBE TEST button is held depressed, and the filament activity test switch is set to TEST position. If the indicator shows a decreased reading after a reasonable time is allowed for the cathode to cool, the useful life of the tube is nearing its end.

RECTIFIER TEST

The circuit used for testing full-wave rectifiers, diodes, and OZ4 (cold-cathode rectifier) tubes is an emission test circuit which is similar to the basic circuit shown in figure 15-45. An a-c voltage of definite value is applied to the

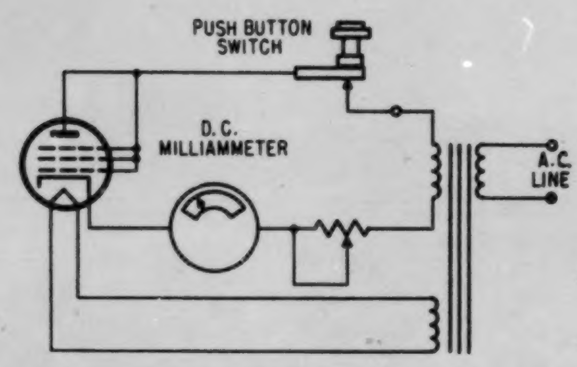


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Figure 15-45.—Basic circuit used for emission test.

tube under test, and the meter indicates the rectified plate current. The two sections of a full-wave rectifier are tested separately.

The button for testing OZ4 tubes provides a higher a-c voltage than is normally used for heater (or filament) type rectifiers. The button for diode tubes provides a lower voltage than that used for regular rectifiers, and also inserts a protective series resistance.

QUALITY TEST

For the quality test, the d-c grid bias for the tube under test is supplied by a rectifier tube. The correct value of this grid bias is obtained when the bias control is rotated to the setting listed in the test data chart, for the tube being tested. An a-c voltage (4.7 volts rms), which is taken from a separate winding on the power transformer, is applied in series with the grid bias. This voltage causes the grid to deviate in positive and negative directions from the d-c bias level, thereby effecting the grid-voltage change required for a dynamic transconductance test. The plate voltage of the tube under test is supplied by a rectifier tube. The meter which indicates the plate current change is in the return circuit of the rectifier supply. The meter indicates the tube condition in arbitrary numerical units from 0 to 120. The tube test data book, mounted inside the cover of the equipment, lists the minimum numerical value of meter reading for satisfactory performance. Tubes reading below this value are not considered suitable for use in military equipment. The shunt control is used to control the sensitivity of the meter. Setting of the dial is required only when the function switch is in the RANGE (A) SHUNT position. The setting for this switch is determined by the type of tube being tested and is listed in the tube data chart.

TESTING TRANSISTORS

Transistors should be checked with the Transistor Test Set TS-1100/U (fig. 15-46). If a test set is not available, it is possible to test transistors with a multimeter or a vacuum tube voltmeter (VTVM).

The TS-1100/U is designed to measure the current gain (beta) and collector leakage current (I_{CO}) of a transistor. It will also detect short circuits.

Beta is defined as the ratio of change in collector current to a change in base current, collector voltage being constant. I_{CO} is a measure of leakage current between the base and collector, when the base-collector junction is reverse-biased and the emitter-base junction is open-circuited.

With a transistor tester, beta may be measured with the transistor in or out of its circuit. You must remove the transistor from its circuit to test for shorts and to measure I_{CO}.

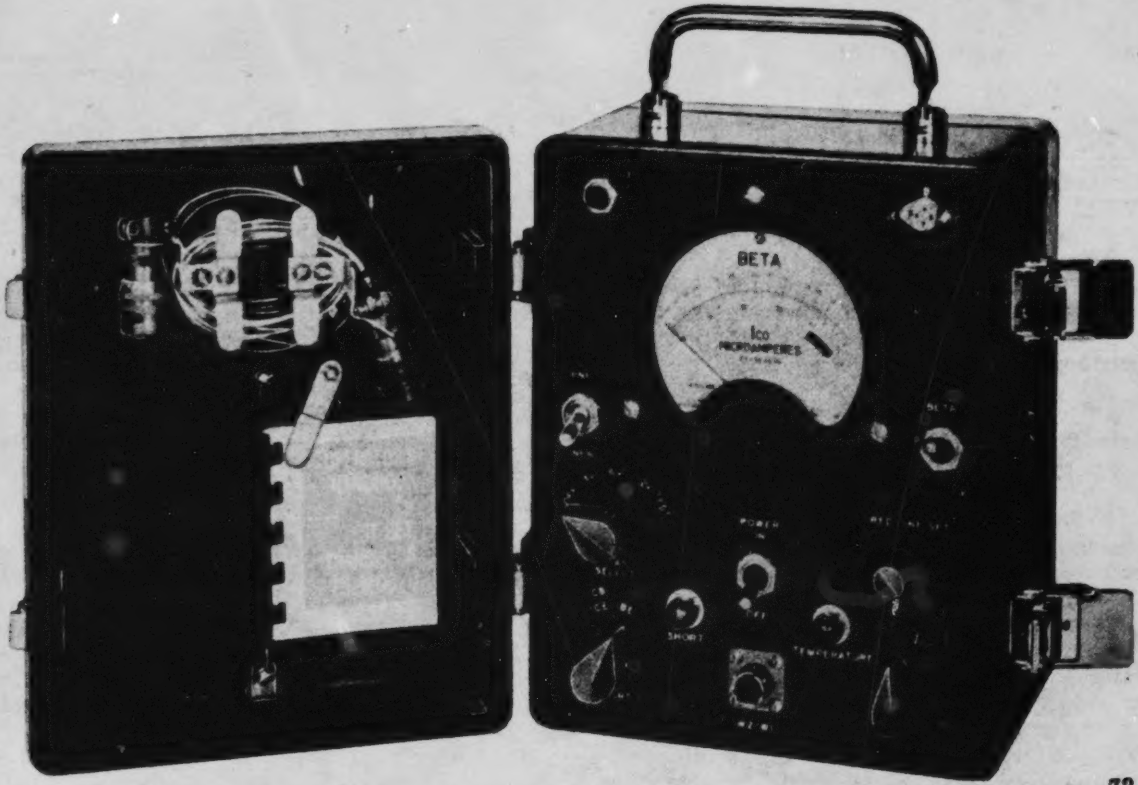
SEMICONDUCTOR TESTING

When using a multimeter to test semiconductors, to avoid loading the circuit, the multimeter must have a sensitivity of at least 20,000 ohms per volt on all voltage ranges; the ohmmeter circuits must not pass a current exceeding 1 milliampere. The VTVM should have an input resistance of 11 megohms or more, and must have an isolation transformer between the meter and the powerline.

Three tests can be accomplished on the transistor by using the multimeter. However, the transistor must be removed from the circuit for testing.

Determine the type of transistor, whether P-N-P or N-P-N. The same resistance test can be performed on the transistor as on the diode. The transistor has two junctions, the emitter-base and the collector-base. Because each junction can be treated as a diode, the same readings hold true.

Before a diode is tested, its polarity must be determined. The diode is usually marked with a plus (+) or minus (-) sign. Connect the test



72.37

Figure 15-46.—Transistor Test Set, TS-1100/U.

leads to the diode in a forward bias condition, that is, the positive lead to the positive side of the diode and the negative lead to the negative side. Current will now flow easily, and if a reading of 1000 ohms or less is obtained, this part of the test is good. If a higher reading is obtained, the diode is open.

Connect the test leads to the diode in a reverse bias condition—the positive lead to the negative side of the diode and the negative lead to the positive side. Current will not flow readily, and a reading in excess of 10,000 ohms should be obtained. If a reading under 10,000 ohms is obtained, the diode is shorted.

As a general rule, the front-to-back ratio should be at least 10 to 1. When testing power transistors, the same ratio (10 to 1) holds true, except that the reverse resistance must be in excess of only 1000 ohms.

Since damage to transistors could occur when using voltages above approximately 6 volts, care must be taken to avoid using resistance scales where the internal voltage of the ohmmeter is greater than 6 volts. This higher potential is usually found on the higher resistance scales. Excess current might also cause damage to the transistor under test. Since the internal current-limiting resistance generally increases as the resistance range is increased, the low range of the resistance scale should also be avoided. Basically, if we stay away from the highest resistance range (possible excessive voltage) and the lowest resistance range (possible excessive current), the ohmmeter should present no problems in transistor testing. Generally speaking, the R x 10 and R x 100 scales may be considered safe.

The polarity of the battery, as well as the voltage value, must be known when using the ohmmeter for transistor testing. Although, in most cases, the ground or common lead (black) is negative and the hot lead (red) is positive, this battery setup is not always the case.

It is possible to reverse the polarity of the ohmmeter leads by changing the function switch position. This means that the black or common lead is now the positive battery and the red lead is the negative battery.

CAUTION:

- Although the jacks of the meter may show a negative sign under the common and a positive sign under the other jack, these do not indicate the internal polarity of the battery connected to the jack.

- Before making any resistance measurements, make sure that all power to the circuit under test has been disconnected and that all capacitors have been discharged.

- Do not use an ohmmeter which passes more than one milliampere through the circuit under test.

- Ensure that all test equipment is isolated from the powerline either by the equipment's own power supply transformer or by an external isolation transformer.

- Always connect a ground lead between COMMON for the circuit under test and COMMON on the test equipment.

- Do not short circuit any portion of a transistor circuit. Short circuiting individual components or groups of components may allow excessive current to flow, thus damaging components.

- Do not remove or replace any transistors in an energized circuit.

I_{CO} TEST

High collector leakage current (I_{CO}) is caused by old age and excessive temperatures. I_{CO} is greatly dependent on ambient temperature, thus care must be taken to see that temperature is controlled when measuring I_{CO}.

One sign of a defective transistor is instability of I_{CO}. Whenever I_{CO} increases slowly while being measured, it is quite evident that the transistor is defective. Excessive leakage current indicates transistor deterioration and usually is accompanied by lower than normal beta. Common causes of excessive I_{CO} include age, high ambient temperature, and contaminates that form on the emitter-base junction or collector-base junction.

Figure 15-47 shows the test circuit for measuring I_{CO}. The transistor must be out of the circuit for this test. If I_{CO} were measured with the transistor in the circuit, the indicated I_{CO} would be higher than the actual I_{CO} due to shunt current paths in the circuit.

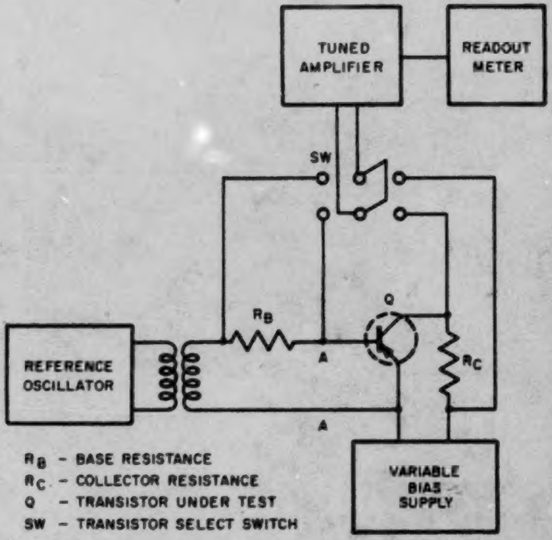


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Figure 15-47.—Measuring beta, using Transistor Test Set, TS-1100/U.

To perform the leakage current test, the manufacturer's specifications should be consulted to ascertain the allowable limits. Determine the type of transistor and set up one of the tests shown in figure 15-48, using a 6-volt battery and microammeter.

If the leakage current is twice as much as the specification sheet calls for, replace the transistor. If no specifications are available, use the following rule of thumb:

1. Silicon transistor—less than 1 microamp.
2. Small germanium transistor—less than 10 microamps.
3. Medium germanium transistor—less than 100 microamps.
4. Power transistors—less than 1 milliampere.

The beta test can be accomplished by inserting a 10,000-ohm resistor between the collector-base junction and connecting the meter to the emitter and collector as shown in figure 15-49.

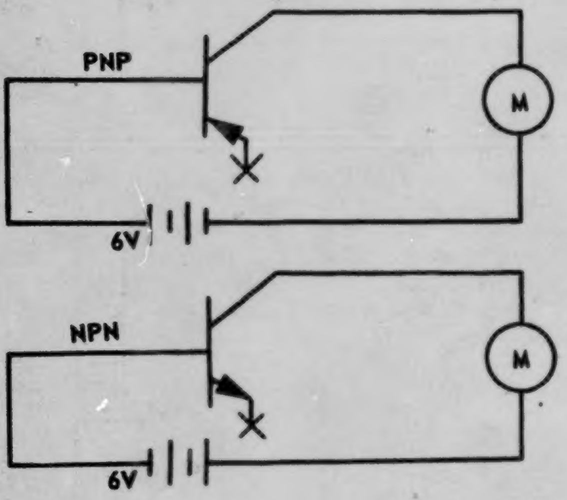

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Figure 15-48.—Transistor leakage current test.

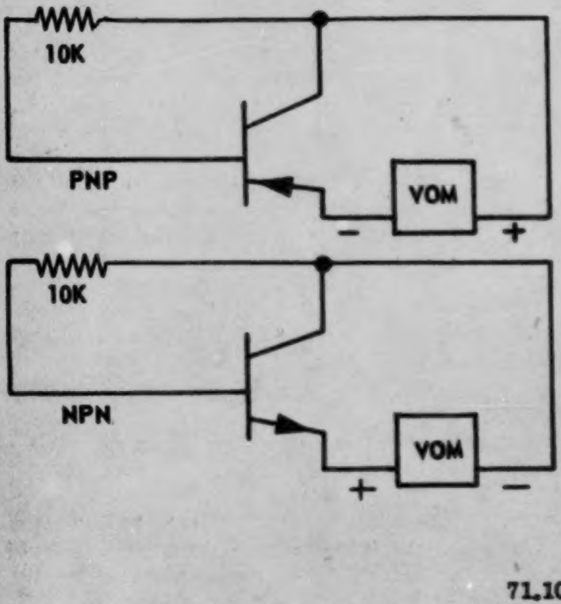

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Figure 15-49.—Transistor gain test.

Once the resistance is obtained on the meter, use the following formula to figure the gain: B = 1200 ÷ R. The letter B represents gain, 1200 is a constant, and R is the resistance read on the meter.

Check the manufacturer's specifications for the gain of each transistor. If the specifications are not available, use the following rule of thumb:

1. Silicon transistors—5 times or more.
2. High-frequency transistors—10 times or more.
3. All other transistors—15 times or more.

Whenever a particular transistor is suspected to be faulty, it may be tested in the circuit if there are no low resistance shunts (such as coils, forward biased diodes, low value resistors, and so forth) across any of its leads. A low resistance shunt across any two of the transistor leads can easily cause erroneous indications on the transistor test set.

Erroneous indications can be eliminated by removing the suspected transistor from the circuit. Some manufacturers have simplified the removal and replacement of transistors by using transistor sockets. Whenever a circuit board without transistor sockets is encountered, transistors will have to be carefully unsoldered in order to test them out of circuits.

MEASUREMENTS IN TRANSISTOR CIRCUITS

The many types of transistor base connection arrangements require that the leads be properly identified to secure correct hookup to the tester. The TS-1100/U test socket arrangement is compatible with some transistor types, but not all types. If the leads are long enough, it is generally possible to effect proper hookup by bending them. If the leads are too short, it will be necessary to use the test cable and alligator clips provided with the tester. In all cases, however, the transistor leads should be identified and then matched up with the tester connections.

The advantage of the TS-1100/U lies not only in its accuracy and simplicity, but also in its use of a-c as the testing current. This eliminates interference from direct currents and voltages that may be present and permits measurement of the gain of a transistor in-circuit, thus making it unnecessary to unsolder or disconnect the the transistor for this test. This is particularly advantageous where the transistor is mounted on a module printed wiring board.

The test set has the following additional features: a switch marked P-N-P-N-P-N, which selects the proper bias polarity for the type of transistor under test; a temperature alarm indicator lamp, which will light when the ambient temperature surrounding the equipment exceeds 50° C; and a switch marked TEST, which checks the test set battery output.

The test set is also equipped to indicate a short between any two of the three elements of the transistor under test. With the transistor in-circuit, it will also indicate a short if the circuitry between any two of the transistor elements has a resistance of 500 ohms or less. To determine whether the short is in the transistor itself or in the associated circuit, it is necessary to remove the transistor from the circuit.

A table in the instruction manual for the test set gives a numerical listing of the transistors that can be tested. The technical manual for the test set provides information concerning the collector bias to be applied for a particular transistor and the maximum permissible collector leakage current. When the instrument is adjusted according to the instruction book, the value of beta will be indicated directly on the meter.

APPENDIX I

THE METRIC SYSTEM

The metric system was developed by French scientists in 1790 and was specifically designed to be an easily used system of weights and measures to benefit science, industry, and commerce. The metric system is calculated entirely in powers of 10, so one need not work with the various mathematical bases used with the English system, such as 12 inches to a foot, 3 feet to a yard, and 5280 feet to a mile.

The system is based on the "meter" which is one ten-millionth of the distance from the Equator to the North Pole. It is possible to develop worldwide standards from this base of measurement. The metric system of weights is based on the gram, which is the weight of a specific quantity of water.

Soon after the system was developed scientists over the world adopted it and were able to deal with the mathematics of their experiments more easily. The data and particulars of their work could be understood by other scientists anywhere in the world. During the early 19th century many European nations adopted the new system for engineering and commerce. It was possible for these countries to trade manufactured goods with one another without worrying whether it would be possible to repair machinery from another country without also buying special wrenches and measuring tools. Countries could buy and sell machine tools and other sophisticated and precision machinery without troublesome modifications or alterations. It was much easier to teach the metric system, since meters can be changed to kilometers or centimeters with the movement of a decimal point, which is roughly like being able to convert yards to miles or inches by adding zeros and a decimal instead of multiplying by 1760 or dividing by 36.

With the exception of the United States, all the industrialized nations of the world have adopted the metric system. Even England and Canada are changing from their traditional systems of measure, and the metric system will be almost universal by 1980.

Although the metric system has not been officially legislated by the Congress, the metric system is becoming more prominent in this country. Most automobile mechanics own some metric wrenches to work on foreign cars or foreign components in American cars. Almost all photographic equipment is built to metric standards. Chemicals and drugs are usually sold in metric quantities, and "calorie counters" are using a metric unit of thermal energy.

Because we are allied with countries who use the metric system, much of our military information is in metric terms. Military maps use meters and kilometers instead of miles, and many weapons are in metric sizes, such as 7.62 mm, 20 mm, 40 mm, 75 mm, and 155 mm. Interchange of military equipment has caused a mixture of metric and English measure equipment since World War I when the army adopted the French 75 mm field gun, and World War II when the Navy procured the Swedish 40 mm Bofors and the Swiss 20 mm Oerlikon heavy machine guns.

It is inevitable that the United States will officially adopt the metric system. Exactly when this happens and how rapidly the changeover will depend on economics, since the expense of retooling our industry and commerce to new measurements will be very great. The cost of conversion will be offset by increased earnings from selling machinery and products overseas. Another benefit is that scientists use the metric system, but their calculations now have to be translated into English measure to be used by industry. With adoption of the metric system ideas can go directly from the drawing board to the assembly line.

The Navy will be using the metric system more during the next few years. Although you will find it easier to solve problems using this system, at first you will find it difficult to visualize or to estimate quantities in unfamiliar units of measure.

Fortunately, many metric units can be related to equivalent units in the English system.

The meter which is the basic unit is approximately one-tenth longer than a yard.

The basic unit of volume, the liter, is approximately one quart. The gram is the weight of a cubic centimeter, or milliliter, of pure water and is the basic unit of weight. As a common weight though, the kilogram, or kilo, which equals the weight of a liter of water, weighs 2.2 pounds. The cubic centimeter (cc) is used where we would use the square inch, and where we measure by the fluid ounce, tne metric system employs the milliliter (ml). For power measure the metric system uses the kilowatt (kW), which is approximately 1.3 horsepower.

In terms of distance, a land mile is eight-fifths of a kilometer and a nautical mile is 1.852 kilometers, or nearly 2 kilometers.

A basic metric expression of pressure is the kilogram per square centimeter, which is 14.2 psi, nearly 1 atmosphere of pressure.

When working on foreign machinery, you may notice that your half-inch, three-quarter inch, and one-inch wrenches will fit many of the bolts. These sizes correspond to 13 mm, 19 mm, and 26 mm respectively in the metric system, and are very popular because they are interchangeable. The 13/16-inch spark plug wrench, which is standard in this country, is intended to fit a 20 mm nut.

The basic quantities of the metric system are multiplied or divided by powers of 10 to give other workable values. We cannot easily measure machine parts in terms of a meter, so the millimeter, or one-thousandth of a meter is used. For very fine measure the micron, also called the micrometer, can be used. It is one-millionth part of a meter, or one-thousandth of a millimeter. For small weights the milligram, one-thousandth of a gram is used. All of these multiples are expressed with standard prefixes taken from Latin:

micro = 1/1,000,000
milli = 1/1,000
centi = 1/100
*deci = 1/10
*deca = 10
*hecto = 100
kilo = 1,000
*myria = 10,000
mega = 1,000,000

* Rarely used

Over the next few years the metric system will become more used by the Navy as well as by the civilian world. You will find it easy to work with once you have mastered the basic terms. It will be difficult to translate values from our present system to the metric system, but this operation will become unnecessary once the new measurements are totally adopted.

Tables of equivalent English measure and metric equivalents are essential when you work simultaneously with both systems. The table which follows shows the equivalent measures of the two systems. The columns on the left have the equivalent values which are accurate enough for most work, and on the right are the multiples used to convert the values with a high degree of accuracy.

U.S. CUSTOMARY AND METRIC SYSTEM UNITS OF MEASUREMENTS

THESE PREFIXES MAY BE APPLIED TO ALL SI UNITS

Multiples and Submultiples	Prefixes	Symbols
1 000 000 000 000 = 10^{12}	tera (tĕr'ȧ)	T
1 000 000 000 = 10^{9}	giga (jĭ'gȧ)	G
1 000 000 = 10^{6}	mega (mĕg'ȧ)	M •
1 000 = 10^{3}	kilo (kĭl'ô)	k •
100 = 10^{2}	hecto (hĕk'tô)	h
10 = 10	deka (dĕk'ȧ)	da
0.1 = 10^{-1}	deci (dĕs'ĭ)	d
0.01 = 10^{-2}	centi (sĕn'tĭ)	c •
0.001 = 10^{-3}	milli (mĭl'ĭ)	m •
0.000 001 = 10^{-6}	micro (mī'krô)	μ •
0.000 000 001 = 10^{-9}	nano (năn'ô)	n
0.000 000 000 001 = 10^{-12}	pico (pē·kô)	p
0.000 000 000 000 001 = 10^{-15}	femto (fĕm'tô)	f
0.000 000 000 000 000 001 = 10^{-18}	atto (ăt'tô)	a

• MOST COMMONLY USED

ENGLISH AND METRIC SYSTEM UNITS OF MEASUREMENT

COMMON EQUIVALENTS AND CONVERSIONS

Approximate Common Equivalents		Conversions Accurate to Parts Per Million (units stated in abbreviated form)	
		Number X Factor	
1 inch	= 25 millimeters	in X 25.4*	= mm
1 foot	= 0.3 meter	ft X 0.3048*	= m
1 yard	= 0.9 meter	yd X 0.9144*	= m
1 mile[†]	= 1.6 kilometers	mi X 1.60934	= km
1 square inch	= 6.5 square centimeters	in^2 X 6.4516*	= cm^2
1 square foot	= 0.09 square meter	ft^2 X 0.0929030	= m^2
1 square yard	= 0.8 square meter	yd^2 X 0.836127	= m^2
1 acre	= 0.4 hectare	acres X 0.404686	= ha
1 cubic inch	= 16 cubic centimeters	in^3 X 16.3871	= cm^3
1 cubic foot	= 0.03 cubic meter	ft^3 X 0.0283168	= m^3
1 cubic yard	= 0.8 cubic meter	yd^3 X 0.764555	= m^3
1 quart (lq.)	= 1 liter	qt (lq.) X 0.946353	= l
1 gallon	= 0.004 cubic meter	gal X 0.00378541	= m^3
1 ounce (avdp)	= 28 grams	oz (avdp) X 28.3495	= g
1 pound (avdp)	= 0.45 kilogram	lb (avdp) X 0.453592	= kg
1 horsepower	= 0.75 kilowatt	hp X 0.745700	= kW
1 pound per square inch	= 0.07 kilogram per square centimeter	psi X 0.0703224	= kg/cm^2
1 millimeter	= 0.04 inch	mm X 0.0393701	= in
1 meter	= 3.3 feet	m X 3.28084	= ft
1 meter	= 1.1 yards	m X 1.09361	= yd
1 kilometer	= 0.6 mile	km X 0.621371	= mi
1 square centimeter	= 0.16 square inch	cm^2 X 0.155000	= in^2
1 square meter	= 11 square feet	m^2 X 10.7639	= ft^2
1 square meter	= 1.2 square yards	m^2 X 1.19599	= yd^2
1 hectare	= 2.5 acres	ha X 2.47105	= acres
1 cubic centimeter	= 0.06 cubic inch	cm^3 X 0.0610237	= in^3
1 cubic meter	= 35 cubic feet	m^3 X 35.3147	= ft^3
1 cubic meter	= 1.3 cubic yards	m^3 X 1.30795	= yd^3
1 liter	= 1 quart (lq.)	l X 1.05669	= qt (lq.)
1 cubic meter	= 250 gallons	m^3 X 264.172	= gal
1 gram	= 0.035 ounces (avdp)	g X 0.0352740	= oz (avdp)
1 kilogram	= 2.2 pounds (avdp)	kg X 2.20462	= lb (avdp)
1 kilowatt	= 1.3 horsepower	kW X 1.34102	= hp
1 kilogram per square centimeter	= 14.2 pounds per square inch	kg/cm^2 X 14.223226	= psi

[†] nautical mile = 1.852 kilometers

* exact

INDEX

A

- ACB breaker, 128
- A-C generator, starting, 299
- AN/PTM-5, telephone test set, 119
- Accident investigation, 33-38
- Accident prevention, 12
- Accident reporting, 33
- Administration, 465-474
- Advancement system, Navy enlisted, 3
- Airfield lighting, 379
  - approach lighting, 380
  - maintenance of marking, lighting, and related electrical facilities, 381
  - standardization, 379
- Air circuit breakers, 128
- Air compressor safety, 80
- Air compressors, 73-80
  - air compressor safety, 80
  - compressed air system, 73
  - compressor operation and maintenance, 75
- Air-conditioners, window, 230
- Air system, conpressed, 73
- Alternating-current stator coils, 208
- Ammeters, 89
- Armatures, 191
- Appendix I, the metric system, 507
- Assignment as crew leader, 465-467
  - planning work assignments, 465
  - supervising work teams, 466
- Auger care and maintenance, 87
- Auger safety, 87
- Augers, power earth, 80
- Automatic boiler controls, 170
  - maintenance, 174
  - pressure limit switch, 171
  - protectorelays, 174
  - safety combustion controls, 172
  - troubleshooting hints, 174
  - water level controls, 170
- Automatic telephone system, 415-421
  - 100-line system, 418
  - 1000-line system, 420
- Automatic telephone system — continued
  - 10,000-line system, 421
  - strowger switches, 415
  - troubleshooting, 421
- Automatic washers, 224

B

- Ball bearings, 189
- Base lead coupling, 495
- Basic electronic components and circuits, 475-506
- Basic measuring instrument precautions, 88
- Basic telephone system components, 385-392
  - hook switch, 391
  - how the telephone works, 385
  - local battery and common battery circuitry, 388
  - magneto generator, 391
  - receiver, 387
  - ringer, 392
  - transmitter, 386
- Basic test equipment, 89-100
  - ammeters, 89
  - clamp-on-voltammeters, 93
  - phase sequence indicator, 99
  - vibrotest megohmmeter, 96
  - voltage tester, 95
- Battalion safety organization, 472
  - key safety personnel, 474
  - safety control and reporting organization, 472
  - safety policy organization, 472
- Battalion table of allowance, 61
- Battery maintenance, 433
- Blueprint reading, 45-48
  - care of blueprints, 45
  - electrical symbols, 48
  - folding blueprints, 45
  - parts of a print, 46
- Blueprints, diagrams and schematics, 45-60
- Bridge, wheatstone, 106
- Brushes, 185
- Brushless generators, 284

Building and switchboard cable, 438
Burns, 42-44
Bus bar, 294

C

Cable classification, telephone, 437
Cable, lead-covered, 437
Cable line, overhead, 395
Cable repairman's test set, 111
Cables, 237
Capacitor color coding, 476
Capacitor motors, 213
Care of instruments, 122
Cathode leakage test, 501
Central power stations, 270-310
Centrifugal switches, 212
Circuit breakers, 128-135
  ACB breaker, 128
  air circuit breakers, 128
  oil circuit breakers, 131
Circuit testing, 433, 477
Circuit, voltage control, 280
Circuits, street lighting, 350
Clamp-on-voltammeters, 93
Classifications, Navy enlisted, 2
Cleaning motors and generators, 215
Closing the sheath, 462
Codes, specifications, 148
Coils, field, 206
Collector rings, 184
Communications maintenance and repair, 433
  battery maintenance, 433
  circuit testing, 433
  intercom system maintenance, 436
  public address system maintenance, 436
  subset maintenance, 434
  switchboard maintenance, 435
  tools and equipment, 436
  wiring maintenance, 433
Communications system, 385-436
Commutators, 180
Compressed air system, 73
Compressor operation and maintenance, 75
Conductors, 236, 250
  service drop, 250
  service entrance, 250
Conductors, locating and installing, 254
Connections to protectors, 403
Construction, primary and secondary, 340
Control and protective equipment, 123-174
Control devices, 157-170
  electrically operated switches, 162
  electronic temperature control, 170
  float switches, 166
  limit switches, 166
Control devices—continued
  manually operated switches, 157
  photoelectric control relays, 162
  pressure and temperature switches, 168
  relays, 162
Controllers, 149-157
  maintenance of controllers, 155
  motor installation identification, 154
  requirements for motor controls and mountings, 154
  reversing controllers, 151
  safety code for motors and motor protection, 154
  types, 149
Controllers, maintenance of, 155
Construction, 357
  ducts and trenches, 357
  manholes and handholes, 357
  underground cable, 360
Coupling methods, 492-495
  direct coupling, 494
  impedance coupling, 493
  RC coupling, 492
  transformer coupling, 494
Crossarms, 312
Crossbar switching system, 421-429
  crossbar switch, 425
  major components, 425
  switching network, 425
  tracing a call, 426
Current transformers, 349

D

Diagrams and schematics, 48-56
  electric appliance and equipment repair, 56
  external distribution systems, 50-52
  interior wiring, 52
  wire communications, 52-56
Diagrams, schematics, and blueprints, 45-60
Diesel and gasoline engine sets, 271
Digging post holes, 319
Diode rectifiers, 482
Diodes, 479-486
  diode rectifier, 482
  electron tube diodes, 479
  solid state diodes, 483
Direct coupling, 494
Disassembly and reassembly, 178
Distribution frames, 398
Distribution panels, 251
Distribution transformers, 338-349
  cooling methods, 340
  grounding transformers, 343

Distribution transformers—continued
  insulating liquids, 341
  primary and secondary construction, 340
  transformer connections, 346
  transformer mounting, 342
  transformer polarity, 345
Domestic oil burners, window air-conditioners, and large appliances, 223
  automatic washers, 224
  electric dryers, 225
  electric hot-water heaters, 227
  hermetic compressor application, 229
  household refrigerators, 233
  oil burners, 223
  ranges, 228
  window air-conditioners, 230
Ducts and trenches, 357

E

Electric appliance and equipment repair, 56
Electric dryers, 225
Electric hot-water heaters, 227
Electric metallic tubing (thin-wall or EMT), 242
Electrical installation, 288-295
  bus bar, 294
  generator connections, 290
  grounding, 288
  reconnecting generator leads, 292
Electrical safety precautions, 24-31
  energized circuits or equipment, 29-31
  lock circuit breaker handles and tag circuits, 26-28
  office machines, 26
  portable equipment, 24
  portable personal equipment, 25
  portable power tools, 24
  replacement of fuses, 26
  switchboards, 28
Electrical shock: causes and consequences, 12
Electrical shop safety, 176
Electrical tester, servivar, 100
Electrically operated switches, 162
Electron tube diodes, 479
Electron tube triodes, 488-490
  oscillators, 489
Electron tubes, multielement, 490
Electron tubes, testing, 497
Electronic temperature control, 170
Emergency shut-down, 303
Engine sets, diesel and gasoline, 271
Engineering command drawings, naval facilities, 56-60
Enlisted rating structure, 2
Entrance switches, 251
Equipment and tools, 176, 436
Equipment, basic test, 89
Equipment, generators, 271-279
Equipment, special test, 100
Erecting poles, 320
Explosion-proof fittings, 248
External distribution systems, 50-52

F

Filament activity test, 501
Field coils, 206
Field switchboard SB-22A/PT, 406
Field telephone systems, 405-413
  field switchboard SB-22A/PT, 406
  field telephone TA-312/PT, 413
  manual telephone central office AN/TTC-7A, 406
Field telephone TA-312/PT, 413-415
  telephone EE-8, 414
Field wires, 394
Fighting fires, 31
First aid, 38-42
  burns, 42-44
  emergency procedures, 39-42
  general, 38
Fixtures, street lighting, 350
Float switches, 166
Freehand sketches, 60
Fuses, types of, 125, 258
  high-voltage, 125
  maintenance, 125
  other fuses, 125
  safety, 127

G

Gas test, 500
Gasoline and diesel engine sets, 271
Generator and motor maintenance, 212
Generator equipment, 271-279
  control panels, 274
  diesel and gasoline engine sets, 271
  generators, 272
  switchboard controls, 278
Generator installation, 285-288
  power and voltage requirements, 285
  sheltering generators, 287
Generator set, preparing to operate, 295
Generator watch, 304
Generators, 272
Generators and motors, repairs to, 178
Generators, operation theory of SRCR, 279
Grounding, 148

Grounding transformers, 343
Guy anchors, 324

H

Hacksaws, power, 67
Hardware, 313
Hermetic compressor application, 229
High-voltage fuses, 125
Hook switch, 391
Horizontal arrangement, 356
Household refrigerators, 233

I

ICO test, 504
Identification of chassis wiring, 479
Impedance coupling, 493
Information sources, 9
    commercial publications, 10
    government publications, 9
    manufacturer's manuals, 10
    training films, 11
Inspecting the generator, 295
Installation, electrical, 288
Installation, generator, 285
Installing a telephone, 402-405
    bells and buzzers, 405
    checking an installation, 405
    connections to protectors, 403
    connections to subsets, 404
    connections to the main run, 404
    hooking up a handset, 405
    wiring, 402
Installing and locating conductors, 254
Installing lighting circuits, 352
Installing the service, 249-257
    distribution panels, 251
    entrance switches, 251
    grounding, 254
    interior wire splices, 257
    locating and installing conductors, 254
    motor branch service, 255
    neutral wire, 253
    service drop conductors, 250
    service entrance conductors, 250
Instruments, care of, 122
Insulating liquids, 341
Insulator pins, 312
Insulators, 312
Intercom system maintenance, 436
Interior wire splices, 257
Interior wiring, 52, 235-269
Interior wiring materials, 236-249
    boxes, 244
    cables, 237
    conductors, 236
    electric metallic tubing (thin-wall or EMT), 242
    explosion-proof fittings, 248
    flexible conduit, 243
    intermediate metal conduit, 243
    PVC conduit, 243
    receptacles, 245
    rigid conduit, 239
    switches, 246
    wiring troughs, 244
Intermediate metal conduit, 243
Interoffice communications systems, 429-433
    installation procedures, 431
    troubleshooting, 432

K

Key safety personnel, 474

L

Lamps, troubleshooting, 267
Large appliances, domestic oil burners, window air conditioners, 223
Lead-covered cable, repair of, 437, 460
Lighting circuits, installing, 352
Lighting systems, 263
Lighting arresters, 317
Line voltage adjustment and test, 499
Local battery and common battery circuitry, 388
Locating and installing conductors, 254

M

Magneto generator, 391
Maintenance of controllers, 155
Maintenance of marking, lighting, and related electrical facilities, 381
Maintenance, motor and generator, 212
Maintenance, switchgear, 306
Manual telephone central office AN/TTC-7A, 406
Manually operated switches, 157
Material and parts, 176
Materials, interior wiring, 236
Measurements in transistor circuits, 505
Metallic tubing, electric (thin-wall or EMT), 242
Methods of biasing, 491
    cathode bias, 491
    grid-leak bias, 491

Metric system, appendix I, 507
Military standards and specifications, 235
Model 259 vibroground, 105
Motor and generator maintenance, 212-223
    capacitor motors, 213
    centrifugal switches, 212
    cleaning motors and generators, 215
    general maintenance, 217
    generators, 215
    sleeve bearings, 220
    split-phase motors, 213
    3-phase motors, 214
Motor branch circuits, 255
Motor installation identification, 154
Motors and generators, repairs to, 178
Multiamp tester (MS-1A), 103
Multielement electron tubes, 490
    pentodes, 491
    tetrodes, 490

N

National electrical code, 235
NAVFAC specifications, 235
Naval facilities engineering command drawings, 56-60
Navy enlisted advancement system, 3
Navy enlisted classifications, 2
Neutral wire, 253

O

Obstruction lighting, 353
    horizontal arrangement, 356
    lighting of overhead wires, 356
    vertical arrangement, 355
Occupational standards, 2
Oil burners, 223
Oil circuit breakers, 131
Open circuits, 262
Open wires, 394
Opening the sheath, 461
Operating and servicing procedures, 297
Operating rules, 304
Operating techniques, 84
Operation of power earth augers, 82
Operation of power station, 299-306
    emergency shutdown, 303
    generator watch, 304
    operating rules, 304
    placing generator on the line, 300
    securing generators, 303
    starting an A-C generator, 299
    synchronizing generators, 300
Operation theory of SRCR generators, 279
Organization, safety policy, 472
Oscillators, 489
Overhead cable line, 395
Overload devices, 135-142
    magnetic type, 139
    thermal type, 141
Overhead power distribution, 311-356

P

PVC conduit, 243
Parts and material, 176
Pentodes, 491
Personnel, key safety, 474
Phase-failure relay, 146
Phase sequence indicator, 99
Photoelectric control relays, 162
Planning work assignments, 465
Plastic-covered cable, 438
Pneumatic drill, 64
Pneumatic grinder, 64
Pneumatic pavement breaker, 65
Polarity, transformer, 345
Pole line components, 312-317
    crossarms, 312
    hardware, 313
    insulator pins, 312
    insulators, 312
    lightning arresters, 317
    poles, 312
    protective devices, 314
Poles, 312
Portable power tools, 61-68
    pneumatic drill, 64
    pneumatic grinder, 64
    pneumatic pavement breaker, 65
    power hacksaws, 67
Power-actuated tools, 68-73
Power and voltage requirements, 285
Power earth augers, 80, 82
    auger care and maintenance, 87
    auger safety, 87
    operation of power earth augers, 82
    operating techniques, 84
    securing a truck-mounted power earth auger, 85
Power hacksaws, 67
Powerline erection, 317-338
    climbing poles, 324
    digging post holes, 319
    erecting poles, 320
    guy anchors, 324
    interference elimination, 337
    mounting crossarms and racks, 332

Powerline erection—continued
  preparing poles, 317
  safety in pole raising, 321
  secondary racks, 332
  stringing the conductors, 333
  tying in conductors, 335
Power rectifier, 307
Power station, operation of, 299
Power tools, portable, 61
Precautions, basic measuring instrument precautions, 88
Preparing a lead splice, 363
Preparing poles, 317
Preparing requisitions, 467
Preparing to operate the generator set, 295-299
  inspecting the generator, 295
  servicing and operating procedures, 297
  servicing the generator, 297
  servicing the prime mover, 296
Pressure and temperature switches, 168
Pressure limit switch, 171
Primary and secondary construction, 340
Prime mover, servicing the, 296
Procedures, servicing and operating, 297
Protective devices, 123-128, 314
  fuse maintenance, 126
  high-voltage fuses, 125
  other fuses, 126
  safety with fuses, 127
  troubleshooting secondary fused circuits, 123
Public address system maintenance, 433, 436
Public works department, 1
  duty at overseas bases, 2
  duty within the U. S., 2
Pulling cable, 360-363
  reel placement, 362
  rigging, 362

R

RC coupling, 492
Rating structure, enlisted, 2
Reading blueprint, 45-48
Reassembly and disassembly, 178
Receptacles, 245
Reconnecting generator leads, 292
Rectifier test, 501
Rectifiers, diode, 482
Refrigerators, household, 233
Repair of lead-covered cable, 460
  closing the sheath, 462
  drying out and repair, 461
  opening the sheath, 461
  soldering the seam, 464
Repairs and maintenance, 257
  disconnecting devices, 258
  fuses, 258
  lighting systems, 263
  load balance, 261
  maintenance, 267
  open circuits, 262
  overloads, 261
  short circuit or ground, 262
  troubleshooting lamps, 267
  wiring systems, 258
Repairs to generators and motors, 178-212
  alternating-current stator coils, 208
  armatures, 191
  ball bearings, 189
  brushes, 185
  collector rings, 184
  commutators, 180
  disassembly and reassembly, 178
  field coils, 206
Resin splice, 378
Resistor color codes, 476
Resistor ratings, 475
Resistor tolerances, 475
Resistors and capacitors, 475-477
  capacitor color coding, 476
  resistor color codes, 476
  resistor ratings, 475
  resistor tolerances, 475
Requirements for motor controls and mountings, 154
Requirements, voltage and power, 285
Reverse current and phase-failure devices, 142-148
  phase-failure relay, 146
  reverse current relay, 142
  reverse-power relay, 144
Reverse power relay, 144
Reversing controllers, 151
Rigid conduit, 239
Ringing machines, 401
Rules, operating, 304

S

Safe working practices, 13-24
  cleaning, 17
  danger from metal objects, 23
  electrical safety references, 16
  fire safety, 14
  grounding, 23
  handtool safety, 15
  installation safety, 15
  insulating floor covering, 19

Safe working practices—continued
  interlocks and safety devices, 23
  ladder safety, 15
  lifting safely, 14
  new installations, 24
  painting electrical equipment, 24
  personal safety, 15
  platforms, 19
  protection of nonelectrical workers, 24
  safety equipment, 17
  shop machinery, 21
  testing rubber protective equipment, 18
  tools, 19-21
  use of warning signs, plates, and tags, 21-23
  walking safely, 14
  wear hard hats, 15
Safety, 12-44, 378
  hot liquids, 379
  manholes, 379
  testing for live cable, 378
Safety, air compressor, 80
Safety, auger, 87
Safety code for motors and motor protection, 154
Safety combustion controls, 172
Safety control and reporting organization, 472
Safety devices and indicators, 306
Safety education, 32-38
  accident investigation, 33-38
  accident reporting, 33
Safety, electrical shop, 176
Safety in pole raising, 321
Safety policy organization, 472
Safety precautions, electrical, 24-31
Schematics, blueprints, and diagrams, 45-60
Schematics and diagrams, 48-56
Secondary racks, 332
Securing a truck-mounted power earth auger, 85
Securing generators, 303
Semiconductor testing, 502
Service drop conductors, 250
Servicing and operating procedures, 297
Servicing the generator, 297
Servicing the prime mover, 296
Servivar electrical tester, 100
Sheltering generators, 287
Shop organization, 175-178
  electrical shop safety, 176
  material and parts, 176
  tools and equipment, 176
Shopwork, 175-234
Short circuit and noise test, 499
Short circuit or ground, 262
Shutdown, emergency, 303
Single source biasing, 495-497
Sketches, freehand, 60
Sleeve bearings, 220
Soldering the seam, 464
Solid state diodes, 483
Special test equipment, 100-122
  cable repairman's test set, 111
  model 259 vibroground, 105
  multiamp tester (MS-1A), 103
  servivar electrical tester, 100
  tela cable model 262, 121
  telephone test set AN/PTM-5, 119
  weston model 639 industrial analyzer type 3, 102
  wheatstone bridge, 106
Special tools, 61-87
Specifications and codes, 148
Specifications and requirements, 235
  military standards and specifications, 235
  NAVFAC specifications, 235
  national electrical code, 235
Splices, interior wire, 257
Splicing lead-sheathed cable, 438
Splicing plastic-sheathed cable to lead-sheathed cable, 449
Splicing polyethylene cable for aerial installation, 446
Splicing polyethylene cable for direct-burial installation, 459
Splicing polyethylene insulated cable, 445
Splicing silk and cotton insulated cable, 445
Splicing telephone cable, 438-460
  splicing lead-sheathed cable, 438
  splicing plastic-sheathed cable to lead-sheathed cable, 449
  splicing polyethylene cable for aerial installation, 446
  splicing polyethylene cable for direct-burial installation, 459
  splicing polyethylene insulated cable, 445
  splicing silk and cotton insulated cable, 445
Splicing underground cable, 363-378
  preparing a lead splice, 363
  resin splice, 378
  splicing with molds, 375
  tapecast splice, 376
Split-phase motors, 213
Starting an A-C generator, 299
Stator coils, alternating-current, 208
Static controls, 279
  operation theory of SRCR generators, 279
Street lighting circuits, 350
Street lighting fixtures, 350
Stringing the conductors, 333
Strowger switches, 415
Subset maintenance, 434
Supervising work teams, 466
Switchboard controls, 278
Switchboard maintenance, 435

Switchboard protective devices, 398
Switchgear maintenance, 306
  safety devices and indicators, 306

Switches, electrically operated, 162
Switches, manually operated, 157
Switches, types of, 166, 246
  float switches, 166
  pressure and temperature switches, 168, 171
Synchronizing generators, 300

T

Tape-armored cable, 437
Tapecast splice, 376
Tela cable model 262, 121
Telephone cable, 394-397
  outside terminals, 396
  overhead cable line, 395
  types of telephone cable, 394
  underground telephone line, 396

Telephone cable classification, 437
  building and switchboard cable, 438
  lead covered cable, 437
  plastic-covered cable, 438
  tape-armored cable, 437
Telephone cable splicing, 437-464
Telephone cable, types of, 394
Telephone EE-8, 414
Telephone line, underground, 396
Telephone switchboards, 397-402
  circuits, 400
  distribution frames, 398
  ringing machines, 401
  switchboard protective devices, 398
  switch key, 402
Telephone system design, 392
  attenuation, 393
  electrical length, 392
  interference, 393
  loading, 393
Telephone test set AN/PTM-5, 119
Terminals, outside, 396
Test equipment, 88-122
Test set, cable repairman's, 111
Testing, circuit, 433
Testing electron tubes, 497-502
  cathode leakage test, 501
  filament activity test, 501
  gas test, 500
  line voltage adjustment and test, 499
  quality test, 502
  rectifier test, 501
  short circuit and noise test, 499

Testing for live cable, 378
Testing transistors, 502
  ICO test, 504
  measurements in transistor circuits, 505
  semiconductor testing, 502
Tetrodes, 490
The personnel readiness capability program, 470-472

Timekeeping, 467-470
Tools and equipment, 176, 436
Tools, portable power, 61
Tools, power-actuated, 68
Transformer connectons, 346
Transformer coupling, 494
Transformers, grounding, 343
Transformer mounting, 342
Transformer polarity, 345
Transformer testing, 477-479
Transmission system planning, 393
  field wires, 394
  open wires, 394

Transmitter, 386
Transistor circuits, measurements in, 505
Transistor lead identification, 487
Transistors, 486-488
  circuitry, 487
  transistor lead identification, 487

Triodes, electron tube, 488
Troubleshooting, 307, 352
  power rectifier, 307
  sectionalizing, 353
  using a megger, 353

Troubleshooting lamps, 267
Troubleshooting secondary fused circuits, 123
Tying in conductors, 335

U

Underground cable, 360
Underground power distribution, 357-384
Underground telephone line, 396
Using a megger, 353

V

Vertical arrangement, 355
Vibroground, model 259, 105
Vibrotest megohmmeter, 96
Voltage and power requirements, 285
Voltage control circuit, 280
Voltage tester, 95

W

Warning, 280-285
  brushless generators, 284
  voltage control circuit, 280
Washers, automatic, 224
Water level controls, 170
Weston model 639 industrial analyzer type 3, 102
Wheatstone bridge, 106
Window air-conditioners, 230
Window air-conditioners, domestic oil burners, and large appliances, 223
Wire communications, 52-56
Wiring, 402
Wiring maintenance, 433
Wiring systems, 258
Wiring troughs, 244

CONSTRUCTION ELECTRICIAN 3 & 2

NAVEDTRA 10636-H

Prepared by the Naval Education and Training Program Development Center, Pensacola, Florida

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Your NRCC contains a set of assignments and self-scoring answer sheets (packaged separately). The Rate Training Manual, Construction Electrician 3 & 2, NAVEDTRA 10636-H, is your textbook for the NRCC. If an errata sheet comes with the NRCC, make all indicated changes or corrections. Do not change or correct the textbook or assignments in any other way.

HOW TO COMPLETE THIS COURSE SUCCESSFULLY

Study the textbook pages given at the beginning of each assignment before trying to answer the items. Pay attention to tables and illustrations as they contain a lot of information. Making your own drawings can help you understand the subject matter. Also, read the learning objectives that precede the sets of items. The learning objectives and items are based on the subject matter or study material in the textbook. The objectives tell you what you should be able to do by studying assigned textual material and answering the items.

At this point you should be ready to answer the items in the assignment. Read each item carefully. Select the BEST ANSWER for each item, consulting your textbook when necessary. Be sure to select the BEST ANSWER from the subject matter in the textbook. You may discuss difficult points in the course with others. However, the answer you select must be your own. Use only the self-scoring answer sheet designated for your assignment. Follow the scoring directions given on the answer sheet itself and elsewhere in this course.

Your NRCC will be administered by your command or, in the case of small commands, by the Naval Education and Training Program Development Center. No matter who administers your course you can complete it successfully by earning grades that average 3.2 or higher. If you are on active duty, the average of your grades in all assignments must be at least 3.2. If you are NOT on active duty, the average of your grades in all assignments of each creditable unit must be at least 3.2. The unit breakdown of the course, if any, is shown later under Naval Reserve Retirement Credit.

WHEN YOUR COURSE IS ADMINISTERED BY LOCAL COMMAND

As soon as you have finished an assignment, submit the completed self-scoring answer sheet to the officer designated to administer it. He will check the accuracy of your score and discuss with you the items that you do not understand. You may wish to record your score on the assignment itself since the self-scoring answer sheet is not returned.

If you are completing this NRCC to become eligible to take the fleetwide advancement examination, follow a schedule that will enable you to complete all assignments in time. Your schedule should call for the completion of at least one assignment per month.

Although you complete the course successfully, the Naval Education and Training Program Development Center will not issue you a letter of satisfactory completion. Your command will make a note in your service record, giving you credit for your work.

WHEN YOUR COURSE IS ADMINISTERED BY THE NAVAL EDUCATION AND TRAINING PROGRAM DEVELOPMENT CENTER

After finishing an assignment, go on to the next. Retain each completed self-scoring answer sheet until you finish all the assignments in a unit (or in the course if it is not divided into units). Using the envelopes provided, mail your self-scored answer sheets to the Naval Education and Training Program Development Center where the scores will be verified and recorded. Make sure all blanks at the top of each answer sheet are filled in. Unless you furnish all the information required, it will be impossible to give you credit for your work. You may wish to record your scores on the assignments since the self-scoring answer sheets are not returned.

The Naval Education and Training Program Development Center will issue a letter of satisfactory completion to certify successful completion of the course (or a creditable unit of the course). To receive a course-completion letter, follow the directions given on the course-completion form in the back of this NRCC.

You may keep the textbook and assignments for this course. Return them only in the event you disenroll from the course or otherwise fail to complete the course. Directions for returning the textbook and assignments are given on the book-return form in the back of this NRCC.

PREPARING FOR YOUR ADVANCEMENT EXAMINATION

Your examination for advancement is based on the Manual of Navy Enlisted Manpower and Personnel Classification and Occupational Standards (NAVPERS 18068-D). The sources of questions in this examination are given in the Bibliography for Advancement Study (NAVEDTRA 10052). Since your NRCC and textbook are among the sources listed in this bibliography, be sure to study both in preparing to take your advancement examination. The standards for your rating may have changed since your course and textbook were printed, so refer to the latest editions of NAVPERS 18068-D and NAVEDTRA 10052.

NAVAL RESERVE RETIREMENT CREDIT

The course is evaluated at 18 Naval Reserve retirement points, which will be credited in units as follows: Unit 1, 12 points upon completion of assignments 1 through 8; Unit 2, 6 points upon completion of assignments 9 through 12. These points are creditable to personnel eligible to receive them under current directives governing the retirement of Naval Reserve personnel. Credit cannot be given again for the course if the student has previously received credit for completing another Construction Electrician 3 & 2 NRCC or ECC.

COURSE OBJECTIVE

In completing this nonresident career course, you will demonstrate a knowledge of the subject matter by correctly answering items on the following: enlisted rating structure; principles of the advancement system; preparing for advancement; safe practices and first aid measures; safety training; reporting accidental injuries or deaths; reading and caring for blueprints, diagrams, and schematics; maintaining and operating test, protective, and control equipment; repairing, testing, and maintaining motors, generators, and electric appliances; fundamentals of interior wiring; installing and operating a central power station; installing, maintaining, and repairing overhead and underground electrical distribution systems; cable splicing; installing, servicing, and operating a telephone communications system; and fundamentals of electronic components and circuits.

While working on this nonresident career course, you may refer freely to the text. You may seek advice and instruction from others on problems arising in the course, but the solutions submitted must be the result of your own work and decisions. You are prohibited from referring to or copying the solutions of others, or giving completed solutions to anyone else taking the same course.

Naval nonresident career courses may include a variety of items -- multiple-choice, true-false, matching, etc. The items are not grouped by type; regardless of type, they are presented in the same general sequence as the textbook material upon which they are based. This presentation is designed to preserve continuity of thought, permitting step-by-step development of ideas. Some courses use many types of items, others only a few. The student can readily identify the type of each item (and the action required of him) through inspection of the samples given below.

MULTIPLE-CHOICE ITEMS

Each item contains several alternatives, one of which provides the best answer to the item. Select the best alternative and erase the appropriate box on the answer sheet.

SAMPLE

s-1. The first person to be appointed Secretary of Defense under the National Security Act of 1947 was
1. George Marshall
2. James Forrestal
3. Chester Nimitz
4. William Halsey

The erasure of a correct answer is indicated in this way on the answer sheet:

	1 T	2 F	3	4	
s-1	■	C	■	■	

TRUE-FALSE ITEMS

Determine if the statement is true or false. If any part of the statement is false the statement is to be considered false. Erase the appropriate box on the answer sheet as indicated below.

SAMPLE

s-2. Any naval officer is authorized to correspond officially with a bureau of the Navy Department without his commanding officer's endorsement.

The erasure of a correct answer is also indicated in this way on the answer sheet:

	1 T	2 F	3	4	
s-2	■	CC	■	■	

MATCHING ITEMS

Each set of items consists of two columns, each listing words, phrases or sentences. The task is to select the item in column B which is the best match for the item in column A that is being considered. Specific instructions are given with each set of items. Select the numbers identifying the answers and erase the appropriate boxes on the answer sheet.

SAMPLE

In items s-3 through s-6, match the name of the shipboard officer in column A by selecting from column B the name of the department in which the officer functions.

A. Officers	B. Departments
s-3. Damage Control Assistant	1. Operations Department
s-4. CIC Officer	2. Engineering Department
s-5. Assistant for Disbursing	3. Supply Department
s-6. Communications Officer	

The erasure of a correct answer is indicated in this way on the answer sheet:

	1 T	2 F	3	4	
s-3	■	C	■	■	
s-4	C	■	■	■	
s-5	■	■	C	■	
s-6	C	■	■	■	

How To Score Your Immediate Knowledge of Results (IKOR) Answer Sheets

	1 T	2 F	3	4	
1	■	C	6	■	1
2	C	9	■	9	2
3	■	■	C	■	
4	CC	12	■	■	1

Total the number of incorrect erasures (those that show page numbers) for each item and place in the blank space at the end of each item.

Sample only

Number of boxes erased incorrectly	0-2	3-7	8-
Your score	4.0	[✓ 3.9]	3.8

Now TOTAL the column(s) of incorrect erasures and find your score in the Table at the bottom of EACH answer sheet.

NOTICE: If, on erasing, a page number appears, review text (starting on that page) and erase again until "C", "CC", or "CCC" appears. For courses administered by the Center, the maximum number of points (or incorrect erasures) will be deducted from each item which does NOT have a "C", "CC", or "CCC" uncovered (i.e., 3 pts. for four choice items, 2 pts. for three choice items, and 1 pt. for T/F items).

Assignment 1

Meet the Construction Electrician: Safety

Textbook NAVEDTRA 10636-H: Pages 1-32

In this course you will demonstrate that learning has taken place by correctly answering training items. The mere physical act of indicating a choice on an answer sheet is not in itself important; it is the mental achievement, in whatever form it may take, prior to the physical act that is important and toward which nonresident career course learning objectives are directed. The selection of the correct choice for a course training item indicates that you have fulfilled, at least in part, the stated objective(s).

The accomplishment of certain objectives, for example, a physical act such as drafting a memo, cannot readily be determined by means of objective type course items; however, you can demonstrate by means of answers to training items that you have acquired the requisite knowledge to perform the physical act. The accomplishment of certain other learning objectives, for example, the mental acts of comparing, recognizing, evaluating, choosing, selecting, etc., may be readily demonstrated in a course by indicating the correct answers to training items.

The comprehensive objective for this course has already been given. It states the purpose of the course in terms of what you will be able to do as you complete the course.

The detailed objectives in each assignment state what you should accomplish as you progress through the course. They may appear singly or in clusters of closely related objectives, as appropriate; they are followed by items which will enable you to indicate your accomplishment.

All objectives in this course are learning objectives and items are teaching items. They point out important things, they assist in learning, and they should enable you to do a better job for the Navy.

This self-study course is only one part of the total Navy training program; by its very nature it can take you only part of the way to a training goal. Practical experience, schools, selected reading, and the desire to accomplish are also necessary to round out a fully meaningful training program.

Learning Objective: Identify fundamentals of staffing a Public Works Department.

1-1. On which of the following factors are staffing requirements of a Public Works Department determined?

1. Size
2. Location
3. Mission
4. All of the above

1-2. A CEC officer who heads the operating division of a Public Works Department has the title of

1. shops engineer
2. leader
3. general foreman
4. group superintendent

1-3. Which of the following blue collar titles carries the most responsibility?

1. Snapper
2. Leadingman
3. Quarterman
4. Chief quarterman

Learning Objective: Point out purposes of general ratings and Navy enlisted classifications (NEC's) and identify skills prescribed by NEC's.

1-4. A general rating is used to identify

1. an individual's job qualifications
2. a specialty used in wartime
3. a broad field of related duties
4. an individual's performance in completing his practical factors

1-5. Navy enlisted classifications are designed to make it easy to exercise management control over

1. CEC officers
2. Navy enlisted personnel
3. officers and enlisted men
4. civilian employees of a Public Works Department

In items 1-6 through 1-8, select from column B the Navy enlisted classification that is assigned to reflect the skills in column A.

	A. Skills	B. NEC's
1-6.	Splicing multiconductor cables used in telephone communication and in electric power transmission and distribution systems	1. CE-5632 2. CE-5642 3. CE-5644
1-7.	Repairing switchboards, telephones, and automatic PBX and PAX telephone exchange equipment	4. EA-5515
1-8.	Repairing electrical systems of shore-based power plants	

1-9. Which of the following tasks would a person assigned the NEC EA-5515 be expected to perform?

1. Placing underwater demolition charges
2. Supervising the collection of pile-driving test data
3. Supervising the day-to-day operation of the safety department
4. Preparing management data associated with one or more construction projects

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Learning Objective: Recognize principles of the advancement system.

1-10. Which of the following is NOT a general requirement to qualify for promotion to CE2?

1. Completion of required training courses
2. Passing a written examination
3. Passing the required performance test
4. Length of time in grade

1-11. Your immediate reward for satisfying all the requirements for advancement is

1. eligibility for promotion
2. actual promotion
3. more prestige
4. more authority and increased responsibility

1-12. Before being transferred to another duty station, you should make sure that your NAVEDTRA 1414/1 is

1. among your personal papers
2. in your service record
3. retained by your division officer
4. destroyed and a new one started at your new duty station

1-13. Which of the courses listed in NAVEDTRA 10052 for the CE rating must a CE2 complete before he is eligible to take a servicewide examination for advancement?

1. All courses listed
2. All courses listed for the next higher rate
3. Asterisked courses listed for the next higher rate
4. Unmarked courses listed for the next higher rate

Learning Objective: Recognize publications for advancement study and point out good study practices.

In items 1-14 through 1-16, select from column B the publication that is the source of the information in column A.

A. Information

1-14. Latest edition of a given Rate Training Manual

1-15. References used as source material for fleetwide advancement examinations

1-16. Skills required of enlisted personnel

B. Publications

1. Manual of Navy Enlisted Manpower and Personnel Classifications and Occupational Standards
2. Bibliography for Advancement Study
3. List of Training Manuals and Correspondence Courses
4. NAVFAC Documentation Index

1-17. Which of the following hints for studying should help you get the most from your Rate Training Manual?

1. Devote your time exclusively to important military topics
2. Try not to cover a complete unit in any one study period
3. Omit easy material; study only the most difficult and the unfamiliar
4. Make notes as you study, particularly of main ideas, then review your notes

1-18. When studying a Rate Training Manual, you should make it a practice to

1. set up a fixed number of pages in each study period
2. relate new information to things you already know
3. memorize as much as you can from a chapter and repeat it to a shipmate
4. concentrate on studying just before an examination so you will not forget important details

1-19. In studying Rate Training Manuals, a reliable indication that you have mastered the subject matter in a chapter is your ability to

1. quote, word for word, passages from the chapter
2. express in your own words the main points of the subject
3. memorize pertinent dates, tables of weights and measures, and other such information
4. ask intelligent questions about the subject

1-20. You can keep abreast of new developments that affect you, your work, and the Navy by

1. obtaining and applying up-to-date information that pertains to your rating
2. collecting personal copies of pertinent technical manuals
3. completing all enlisted correspondence courses that pertain to your rating
4. completing all officer correspondence courses that are related to your rating

1-21. Which of the following publications is published by the National Bureau of Standards?

1. National Electrical Code
2. National Electrical Safety Code
3. Navy Safety Precaution for Shore Activities
4. Advanced Base Electrical Systems

Learning Objective: Recognize safe practices in the use of tools and equipment and identify publications that provide information on electrical safety.

1-22. The extent of body damage caused by electrical shock depends on

1. the size of the body
2. the value of voltage touched by the body
3. the amount of current flow through vital organs
4. whether the current was a-c or d-c

1-23. When the human body is shocked by more than 200 ma of current, the chest muscles contract to clamp the heart.

1-24. Which is the most important factor in rescuing a man in contact with an electric circuit?

1. Preventing physical injury to the man
2. Separating the man from the electric power by the quickest possible means
3. Preventing the victim's body resistance from decreasing
4. Avoiding damage to equipment

1-25. The procedure for discharging a charged capacitor is to discharge it

1. twice for at least 10 seconds each time
2. once for at least 10 seconds each time
3. once for at least 5 seconds each time
4. twice for at least 5 seconds each time

1-26. In what position should your feet, knees, and back be when you are lifting an object?

1. Feet apart 15 inches from object, knees bent, and back straight
2. Feet apart close to object, knees straight, and back bent
3. Feet together and close to object, knees bent, and back straight
4. Feet together 15 inches from object, knees straight, and back straight

1-27. When placing an 8-ft ladder against a wall, how far from the wall should you set the base of the ladder?

1. 1 ft
2. 1 1/2 ft
3. 2 ft
4. 2 1/2 ft

1-28. In climbing a ladder while carrying tools, you should make it a practice to carry the tools

1. in both hands; use no hands for climbing
2. in the right hand; use the left hand for climbing
3. in the left hand; use the right hand for climbing
4. in a bag slung over the shoulder; use both hands for climbing

1-29. Which of the following tasks requires that goggles be worn?

1. Soldering an electrical connection
2. Pouring acid into water
3. Drilling holes in concrete or other masonry materials
4. Each of the above

1-30. Hard hats provide better head protection than ordinary hats. Which of the following is another true statement in favor of wearing hard hats instead of conventional headgear?

1. Hard hats weigh less
2. Hard hats keep the head cooler on hot, sunny days
3. Hard hats keep the neck and ears warmer in cold weather
4. Hard hats stay on the head in high winds without benefit of a chinstrap

1-31. What advice should you give one of your men who objects to wearing a hard hat because it does not keep his head, neck, or ears warm?

1. Wear a stocking cap over the hard hat
2. Wear ordinary headgear made of extra thick material
3. Wear a winter liner
4. Use a chinstrap to keep the hard hat in place

1-32. The wiring specifications contained in NAVFAC Specifications are based on minimum requirements for safe design of electrical installations which the National Fire Protection Association provides in

1. Handbook H-30
2. National Electrical Code
3. National Electrical Safety Code
4. Safety Precautions for Shore Activities

1-33. Handbook H-43 contains engineering data for the installation and maintenance of electrical and communications lines. The name of this publication is

1. Installation and Maintenance of Electrical Supply and Communication Lines, Safety Rules and Discussion
2. National Electrical Safety Code
3. Safety Precautions for Shore Activities
4. Safety Rules for the Installation and Maintenance of Electric Supply and Communication Lines

1-34. When a rubber glove is being air-tested for holes, air is trapped in the glove and forced into the thumb, fingers, and palm of the glove. Any hole through which air can escape is found by

1. submerging the glove in water and watching for bubbles of air to rise to the surface of the water
2. coating the glove with a soapsuds solution and watching for soap bubbles to form
3. Holding the glove to your ear and listening for the sound of escaping air

1-35. Which of the following is a safe practice?

1. Cleaning an electrical apparatus with a flammable fluid
2. Wearing a hard hat when working or walking in an area where hoisting or overhead work is going on
3. Shifting positions of your feet while lifting a heavy object
4. Sharpening gaffs on pole climbers when gaff length measures less than 1 1/4 inches

1-36. Which of the following materials is suitable for covering grounded metal to keep a worker from coming in contact with the metal?

1. Damp plywood
2. Dry canvas that has holes in it
3. Dry insulating material that contains no holes or conductors
4. Dry phenolic material that has a conductor embedded in it

1-37. If it becomes necessary to work on electrical circuits or equipment in wet or damp locations, what is one very important step you should take?

1. Making sure that there is no contact between the wet floor and your shoes
2. Wearing shoes that have thick rubber soles
3. Wiping the area where you are going to stand with a dry rag

1-38. Which of the following actions is an approved method for improvising an insulating barrier between a metal tool and the hand of its user?

1. Applying cambric sleeving covered by several layers of friction tape
2. Applying several layers of friction tape
3. Applying several layers of approved rubber insulating tape (half-lapped) covered by a layer or two of friction tape

1-39. A metal tool handle may be covered with several layers of rubber tape, and then covered with a layer of friction tape for emergency electrical use.

1-40. What should you do if a powder-actuated tool misfires, or fails to fire, after a period of 15 seconds?

1. Open the tool, remove the powder charge, then remove the guard
2. Remove the guard from surface and then remove the charge
3. Replace the charge and then attempt to refire

1-41. If you are called while soldering the connections to a motor and have to leave your shop for a few minutes, what should you do with the hot soldering iron?

1. Display a HOT HAZARD sign and return as soon as possible
2. Leave it plugged in so others will see that it is hot
3. Retin it and leave it plugged in
4. Unplug it and stow it in its assigned storage area

1-42. Which of the following procedures is recommended for cleaning a soldering iron?

1. Hold a cleaning cloth in your hand and wipe the hot iron across it
2. Place a cleaning cloth on a suitable surface and wipe the hot iron across it
3. Swing the hot iron with enough force to remove the solder
4. Tap the hot iron on a metal surface to knock the solder off

1-43. Which of the following measures is considered the final touch in the completion of a high voltage equipment installation?

1. It is checked by the electrical officer
2. It is checked by the division's leading CPO
3. It is tested by an experienced operator
4. High voltage warning signs are posted in full view of operating personnel

1-44. Warning signs are posted in work areas to alert individuals of existing hazards and to prevent damage to machinery.

1-45. What are the ground lead requirements for an electrical workbench that is 8 feet long?

1. One 8-foot ground lead
2. Two 8-foot ground leads
3. Two 4-foot ground leads
4. Three 3-foot ground leads

1-46. Which of the following sizes of ground lead is appropriate for a workbench that is supplied by 12-gage line conductors?

1. 10-gage
2. 14-gage
3. 18-gage
4. 20-gage

1-47. What is the maximum acceptable resistance between an installed grounding object and the earth?

1. 1 ohm
2. 3 ohms
3. 6 ohms
4. 12 ohms

1-48. What is the primary purpose for repainting electrical equipment?

1. To prevent incipient corrosion
2. To improve its appearance
3. To improve the insulation
4. To provide a means of identification

1-49. Portable electric cables should be considered very dangerous if they are

1. more than 10 feet long
2. spliced at any place
3. insulated with any material other than rubber
4. red

1-50. Which of the following procedures apply to portable, electrical personal equipment?

1. Inspection every 6 months
2. Repair and reinspection by the electrical crew, if damaged
3. Certification by means of a Safety Officer's tag of approval before use
4. All of the above

1-51. Assume that the personal radio belonging to one of your men has a built-in power transformer that presumably provides isolation from the powerline, but you have found that the insulation resistance between the metal chassis of the radio and the primary of the transformer is only three megohms. What safety measure do you take?

1. Check the tubes and replace the defective ones
2. Ground the chassis by means of a grounded plug and suitable cord
3. Insert an additional resistance, approximately 100 megohms, in series with the primary of the transformer
4. Reverse the leads to the secondary of the transformer

1-52. Electric shavers do not require 3-prong gounding plugs because the

1. owner cannot use it ashore
2. original cord is fused to the housing to prevent it from being pulled out
3. housing is of nonconductive plastic material and the cutting blades are isolated from the electrical components within the shaver
4. 3-conductor cord is too heavy and bulky which makes it hard to use

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Learning Objective: Recognize safe and unsafe working practices or conditions applicable to energized circuits.

1-53. Which of the following is a safe practice for members of an electrical crew?

1. Wearing rubber gloves with leather overgloves to remove transformer fuses
2. Placing a NAVSHIPS Warning Tag 3950 (3-63) on each switch of a circuit that is being overhauled
3. Placing 2 NAVSHIPS Warning Tags 3950 (3-63) on each supply switch of a circuit that is being repaired by 2 working parties
4. Each of the above

1-54. What is the first step that you should take in replacing a 220-volt 15-ampere fuse?

1. Deenergize the circuit completely
2. Put on rubber gloves before touching the fuse
3. Remove and replace the fuse with insulated fuse pullers
4. Turn the switch off to the burned out fuse only

1-55. What are metal locking devices used for?

1. Locking switches in the ON position to stop them from tripping in case of a surge in power
2. Locking switches in the OFF position to prevent them from being operated accidentally
3. Securing circuits which are no longer in use
4. All of the above

1-56. After the power has been turned off and the switch locked and tagged, you still should not proceed to work on the circuit until you have checked

1. your tools
2. the lights in the space
3. the metering and control circuits
4. the grease and oil fittings

1-57. Which of the following circuit breakers should be secured before work is started on a switchboard?

1. The main circuit breaker to the switchboard
2. The circuit breaker at the generator feeding the switchboard
3. All circuit breakers leading to the switchboard
4. All of the above

1-58. One of the requirements of a rear-service switchboard is that

1. the fuse box be behind the switchboard
2. it must be dusted every day
3. the rear of the switchboard be covered with an expanded metal enclosure
4. it be painted with bright colors to identify the circuits

1-59. Who determines whether or not work is done on an energized circuit?

1. Electrical officer only
2. Damage control officer only
3. Engineering officer only
4. Commanding officer or his authorized representative

1-60. Before work is started on an energized circuit or switchboard, a Construction Electrician should check to make sure that

1. the division officer is present
2. a Hospital Corpsman is present in case of an accident
3. the safety officer is present
4. men are stationed by circuit breakers or switches and telephones are manned

1-61. What is the recommended procedure for discharging high voltage capacitors when checking a circuit?

1. Discharge once with a suitably insulated shorting or grounding bar
2. Discharge at least twice, with a minimum 15-second interval
3. Discharge when the power is turned off and again before starting to work on the circuit
4. Connect a jumper lead across the capacitor leads but be sure to remove it before energizing the circuit

1-62. Which of the following practices must NOT be followed when you are taking measurements on electrical circuits or equipment?

1. Deenergize the equipment after taking the reading
2. Assign the responsibility of energizing the equipment to an assistant standing by the switch
3. Avoid touching the test instrument while the power is on
4. Take the measurement directly by means of flexible leads or probes.

1-63. Which of the following is NOT a requirement for working on live conductors and equipment operating at 600 volts or less?

1. Adjacent live or grounded conductors and equipment should be covered with insulating material or approved rubber protective equipment
2. Bare or exposed places on one conductor must be taped or covered before another conductor is exposed
3. Two men should work together
4. One must maintain a body clearance of 2 feet when working on energized lines

1-64. When you are testing a 2,000-volt circuit to determine if it is alive and it is not possible to recheck the voltage detector on a known live circuit, what must you do?

1. Test the voltage detector on a live circuit in the electric shop before work is started
2. Ask personnel who have used the detector if it is working properly
3. Use a new detector
4. Check it two times, each with a different detector

1-65. When working on electrical equipment with operating voltages of 3 to 7.5 kilovolts, 7.5 to 12 kilovolts, or 12 to 33 kilovolts, you should maintain a minimum distance of, respectively

1. one-half foot, 1 foot, and 2 feet
2. one-half foot, 2 feet, and 3 feet
3. 1 foot, 2 feet, and 3 feet
4. 2 feet, 3 feet, and 4 feet

1-66. Under which of the following conditions may work be performed with hot-line tools on lines energized at more than 5,000 volts?

1. Rain is impending but not actually falling
2. Snow is falling but rubber gloves are worn
3. Tools are dry and rubber gloves are not worn
4. All of the above

1-67. The world's most important protective agent is

1. a careful individual
2. a good safety training program
3. use of safety procedures
4. good safety equipment

Learning Objective: Indicate fire control and fire preventive measures.

1-68. The best way to extinguish an electrical fire is to turn off the power and cover the fire with

1. foam
2. carbon dioxide
3. sand
4. water

1-69. How soon after the discharge of a fire extinguisher should you request a recharge or replacement?

1. Immediately
2. After a damage estimate has been made
3. At the next firefighting equipment inspection
4. Within 1 week after the fire

1-70. What should be done with wiping rags and other flammable waste material?

1. Place them in a cardboard box and keep the box behind the motors and generators
2. Place them in a tightly closed metal container and empty the container at the end of each work day
3. Place the rags so they may be reached easily and place other waste material in a tightly closed metal container
4. Remove them from the work area and place them in a neat pile in an open area

1-71. When not in use, volatile solvents should be kept in tightly closed containers and stored in a separate building or in

1. a ventilated fire-resistant room
2. the coolest part of the generator room
3. the supply room
4. an area just outside the generator room but protected from the sun

Assignment 2

Safety (continued): Blueprints, Diagrams and Schematics; Special Tools

Textbook NAVEDTRA 10636-H: Pages 33-87

Learning Objective: Point out some important aspects of safety training and identify information that must be entered on the Accidental Injury/Death Report, OPNAV Form 5100/1.

2-1. Sound safety training enables a man to guard against hazards for which safety devices are impracticable.

2-2. Which of the following will be most beneficial in reducing accidents?

1. Never work on unfamiliar equipment
2. Memorize all safety precautions
3. Work slowly and deliberately
4. Recognize hazardous situations

2-3. Which of the following measures is the preferred method for making the men in your electrical group safety conscious?

1. Allow them to learn by experience
2. Provide them with safety reminders and your personal example
3. Restrict them if they fail to follow the safety rules
4. Send them to safety school

2-4. Completing the reverse side of an accident report (OPNAV Form 5100/1) provides the crew leader with a guide for

1. summarizing safety lectures and movies that focus on accident prevention
2. recommending action that will help prevent accidents similar to the one being reported
3. describing the type of injury
4. organizing a training program that will emphasize accident preventions

2-5. The main purpose for completing sections 22 and 24 of the Accidental Injury/Death Report, OPNAV Form 5100/1, is to

1. recommend corrective actions
2. identify the principal unsafe condition or act that caused the accident
3. provide a detailed description of the accident
4. determine whether or not a formal investigation of the accident is required

2-6. What kind of information should you supply in section 27 of the Accidental Injury/Death Report, OPNAV 5100/1?

1. Your description of the accident
2. Your opinion as to whether the accident was caused by an unsafe act or not
3. Your opinion as to whether or not the accident was caused by an unsafe condition
4. Your opinion of what can be done or what will be done to prevent accidents like the one being reported

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Learning Objective: Indicate injuries encountered in electrical work and recognize procedures for rendering first aid to accident victims.

2-7. As a general rule in aiding accident victims, which type of injury poses the greatest threat to life and requires the most immediate treatment?

1. Stoppage of breathing
2. Wounds, fractures, and dislocations
3. Shock
4. Serious bleeding (hemorrhage)

2-8. One of the symptoms of a person in shock is

1. a weak pulse
2. constracted pupils
3. cold, dry skin
4. deep, fairly regular breathing

2-9. Which of the following is the most important factor in trying to rescue a man from contact with an electric circuit?

1. Securing the circuit quickly
2. Pulling the man away from the circuit quickly
3. Starting artificial resuscitation as soon as possible
4. Avoiding contact with the live circuit or with the victim while he is in contact with it

2-10. What must you do for the victim of electrical shock before beginning artificial respiration?

1. Administer a stimulant
2. Treat him for shock
3. Clear his mouth of foreign matter or other obstruction
4. Cover him with a blanket

2-11. Indications of a cardiac arrest include

1. cold and moist skin, weak pulse at the wrist, and shallow, irregular breathing
2. dilated pupils of the eyes, complete absence of pulse at the wrist, and weak or stopped breathing
3. contracted pupils of the eyes, complete absence of pulse at the wrist, and weak or stopped breathing
4. contracted pupils of the eyes, weak pulse at the wrist, and cold and moist skin

2-12. When giving a cardiac massage, you should place your hands one on top of the other so that the heel of the bottom hand covers the

1. lower part of the breastbone and the fingers of the top hand point toward the victim's neck
2. upper part of the breastbone and the fingers of the top hand point toward the victim's neck
3. lower part of the breastbone and the fingers of the top hand point toward the victim's feet
4. upper part of the breastbone and the fingers of the top hand point toward the victim's neck

2-13. When giving a cardiac massage you should repeat the application of pressure about

1. 40 to 60 times per minute
2. 50 to 70 times per minute
3. 60 to 80 times per minute
4. 70 to 90 times per minute

Information for items 2-14 through 2-20. You are first to arrive at the scene of a fire. You find the following casualties injured as indicated.

Poindexter--right hand and forearm are reddened and blistered.

Anderson--entire left leg exhibits symptoms of increased warmth, tenderness, and a reddish appearance.

Stein--face, neck, and both arms are reddened and blistered; skin on both hands is completely destroyed and the underlying tissue is black.

Laine--burn on his right leg from the knee down, is characterized by complete destruction of the skin, with charring and cooking of the deeper tissues.

2-14. Your main objectives in rendering first aid treatment to burn victims are to

1. prevent infections, relieve pain, and combat shock
2. relieve pain, immobilize the burned areas, and apply antiseptics to the burns
3. combat shock, open blisters, and apply wet antiseptic dressings to the burns
4. remove foreign materials from the burns, apply hot moist packs to the burns, and prevent infections

2-15. The casualty who is most seriously burned is

1. Poindexter
2. Anderson
3. Stein
4. Laine

2-16. The casualty who has only first degree burns is

1. Poindexter
2. Anderson
3. Stein
4. Laine

2-17. Poindexter and Stein are experiencing more pain than Anderson and Laine.

2-18. In treating Stein for shock, what exception should you make to the general procedure of shock treatment?

1. Keeping him cool
2. Giving him liquids by mouth
3. Placing him in a sitting position
4. Giving him 1/2 grain of morphine

2-19. Clothing or other foreign material adhering to a severly burned area of the body should be

1. removed carefully, with a sterile pointed stick
2. soaked loose in warm saltwater
3. cleansed from the area with soap and water
4. left alone

2-20. If battery acid spills on your skin, the first thing you should do is

1. wipe the acid off with a clean, dry rag
2. wipe the acid off with a clean, wet rag
3. rinse the acid away with plenty of cold, fresh water
4. neutralize the acid with ammonia or baking soda

Learning Objective: Define the term blueprint and identify its main part.

2-21. What is the definition of a blueprint?

1. Information extracted from a drawing
2. A reproduction of the working drawing of a schematic
3. A drawing reproduced on blue paper only

2-22. The main part of a blueprint for a machine is the

1. bill of material for the machine
2. title block
3. legend
4. graphic representation of the machine

Learning Objective: Point out procedures to follow in reading and caring for blueprints and identify symbols used on electrical drawings.

2-23. Which of the following is a necessary practice in the proper care of blueprints?

1. They should never be folded
2. They should be kept out of sunlight
3. Only pencil should be used to make notations on them
4. Each of the above

2-24. After refolding a blueprint, you should be able to see its identifying number without having to unfold the print.

2-25. Knowing the drawing number on a blueprint enables you to properly file the print. The drawing number also serves to

1. identify the type of system described in the drawing
2. indicate the overall size of the object described
3. help in locating a drawing referenced on another print

2-26. The quantity, stock number, and description of all items required for a wiring job are listed in which part of the blueprint?

1. Legend
2. Title block
3. Notes
4. Bill of material

2-27. In planning a job, you are working from a drawing and need to know how many feet of conduit to order. Which of the following techniques would give you the most accurate results?

1. Measure the lines on the drawing, and convert them to scale
2. Trace out the conduits on the drawing, then estimate the length of each run
3. Copy the dimensions of conduit from the drawing and add them
4. Refer to the schematic for the job

2-28. What part of a print explains the abbreviations and item numbers shown on the print?

1. Legend
2. Block diagram
3. Title block
4. Scale

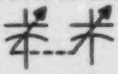
2-29. Assume you are reading an electrical blueprint and do not understand the meanings of various symbols shown. Which of the following standards should you consult to find the meanings of these symbols?

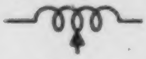
1. Military Standards for Electrical Symbols
2. American National Standard Institute's Standard Y 32.9
3. Each of the above

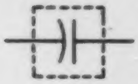
2-30. In learning to read an electrical drawing, you try to see the mental picture that symbols, abbreviations, and notes make.

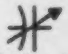
● Refer to table 3-1 of your textbook when answering items 2-31 through 2-34.

2-31. Which of the following graphic symbols represents a shielded capacitor?

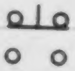
1. 

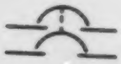
2. 

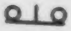
3. 

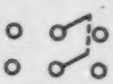
4. 

2-32. Which of the following graphic symbols represents a pushbutton two-circuit switch?

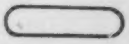
1. 

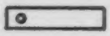
2. 

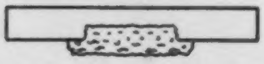
3. 

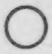
4. 

2-33. Which of the following is the standard architectural symbol for a single fluorescent fixture?

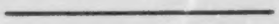
1. 

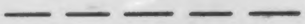
2. 

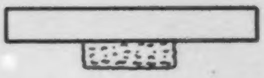
3. 

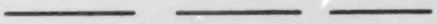
4. 

2-34. The architectural symbol for a surface-mounted panelboard and cabinet is

1. 

2. 

3. 

4. 

Learning Objective: Apply electrical diagrams and schematics to internal and external wiring and communications systems.

● The following alternatives are for items 2-35 through 2-37.

A. Schematic diagram

B. Plot plan

C. Wiring diagram

D. Pictorial diagram

2-35. Which type of drawing is helpful in determining where the connections are to be made in an electrical circuit?

1. A
2. B
3. C
4. D

2-36. When used to illustrate a given electrical hookup, which type of drawings would show the same components?

1. A, B, and C
2. A, C, and D
3. B, C, and D
4. A, B, C, and D

2-37. Which type of drawing gives you an idea of what the equipment looks like?

1. A
2. B
3. C
4. D

2-38. Refer to textbook figure 3-5. What is the voltage and phase of the primary mains leading to the battalion's mess hall?

1. 208-volt, 3-phase
2. 240 volt, 1-phase
3. 240 volt, 3-phase
4. 120 volt, 3-phase

2-39. The distribution system of textbook figure 3-6 feeds three phase power to operate the motor pool lighting system and 120-volt motor.

- When answering items 2-40 through 2-42, refer to textbook figure 3-7.

2-40. About how much No. 2 wire will be needed between the pole next to manhole 22 and the pole near building 126?

1. 2,300 ft
2. 2,000 ft
3. 1,500 ft
4. 700 ft

2-41. If each guy wire is made up of 45 feet of 3/8-inch steel cable, how many feet of this cable and how many strain insulators are needed for the job?

1. 180 ft of cable and 8 insulators
2. 225 ft of cable and 10 insulators
3. 270 ft of cable and 10 insulators
4. 270 ft of cable and 12 insulators

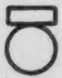
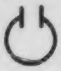
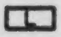
2-42. How much of the line poles will be above ground when they are set?

1. 29 ft
2. 35 ft
3. 40 ft
4. 41 ft

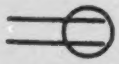
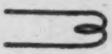
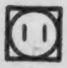
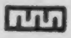
2-43. The dotted lines in textbook figure 3-8 represent

1. fencing
2. underground conduit
3. bonding wire
4. overhead ducts

2-44. Which of the following is the standard architectural symbol for a lighting panel?

1. 
2. 
3. 
4.

2-45. The architectural symbol for a convenience outlet is

1. 
2. 
3. 
4. 

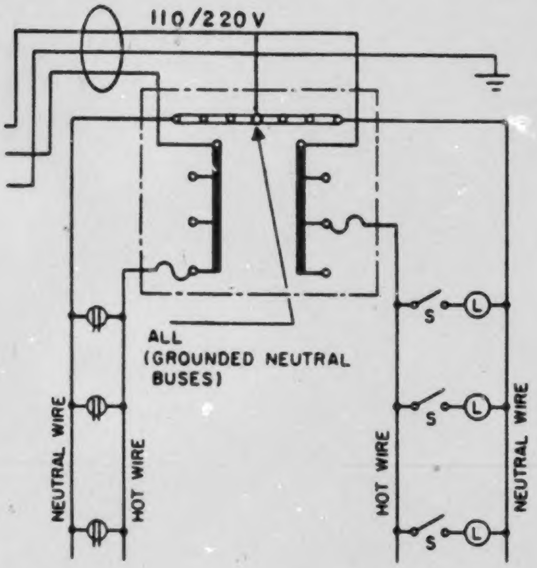


Figure 2A

● When answering items 2-46 through 2-48, refer to figure 2A.

2-46. It is possible to run a 220-volt, 3-phase motor from this panel.

2-47. The panel board is equipped to handle six circuits but only two are in use.

2-48. A single switch is used to disconnect power from all the convenience outlets.

2-49. How are P and S of the induction coil placed in series in textbook figure 3-11A?

1. Energizing coil LR1
2. Deenergizing coil LR1
3. Taking the receiver off the hook
4. Closing switch LJ1

2-50. Line lamp LL1 in figure 3-11A is energized

1. when relay LR1 deenergizes
2. when relay LR1 energizes
3. only when the transmitter is deenergized

2-51. You are to install an electric range in the galley. Which of the following best describes the information obtainable from textbook figure 3-12?

1. Each heating coil will be rated at 600 watts
2. Each heating coil will be rated at 300 watts
3. Each heating coil is wired to operate on 230 volts
4. Each range unit should be fused for at least 15 amperes

Learning Objective: Point out advantages, disadvantages, and applications of NAVFAC prepared standard drawings.

2-52. The advanced base drawings in NAVFAC P-437 save construction time because

1. they are easier to use than the normal types of blueprints
2. all buildings constructed by SEABEES are basically the same
3. they permit much work to be done on an assembly line basis when several similar structures are to be built
4. they provide a standard plan for all shop installation

2-53. Which of the following is a disadvantage of the standard drawings prepared by NAVFAC for use at an advanced base?

1. A single master plan cannot be used for all buildings
2. They add to the time it takes to wire buildings for heating and lighting
3. They create more installation problems than they solve
4. They exclude detailed information on proper installation of equipment

2-54. Study the print in textbook figure 3-15. What do the numbers on the 50 ampers, 3-phase panelboard indicate?

1. Circuit breaker mounting bolt sizes
2. The output voltage of each circuit
3. The circuit breaker each circuit ties into from the main panel

2-55. Where on a blueprint would the electrician find information as to special instructions needed to complete an assembly?

1. Notes on the bill of material
2. Notes written in the margins of the print
3. Directly beneath the assembly number

Learning Objective: Identify special tools and fundamentals of operating and caring for them.

2-56. Power tools used by a construction electrician in an NMCB are to be found in the

1. electrician's toolkit
2. lineman's toolkit
3. central toolroom

2-57. The speed of a pneumatic drill is controlled by means of the

1. air compressor
2. throttle valve
3. handle switch
4. feed screw

2-58. The rapid wear of the moving parts of a pneumatic grinder is the result of

1. improper lubrication
2. excessive speed
3. underloading
4. excessive air pressure

2-59. The attachment on a pneumatic pavement breaker for cutting asphalt and frozen ground is a

1. moil point
2. spade
3. chisel point
4. tamper

2-60. Which of the following is a good practice in the operation of a pneumatic pavement breaker?

1. Taking bites of 4 to 8 inches behind the working face
2. Taking bites of 4 to 8 inches in front of the working face
3. Drilling holes with the moil point
4. Breaking concrete with the chisel point

2-61. By not shutting off the pavement breaker when the moil point breaks through concrete, you are likely to end up with a broken

1. moil point
2. shank holder
3. shank
4. retainer bolt

2-62. Of the following types of power hacksaws, with which can you increase or decrease the pressure on the material being cut?

1. Hydraulic
2. Mechanical
3. Gravity
4. Feed

2-63. What should be the pitch of a power hacksaw blade for cutting a solid piece of brass stock?

1. 4 teeth per inch
2. 6 teeth per inch
3. 10 teeth per inch
4. 14 teeth per inch

2-64. In operating power-assisted hammers, you will need one piston for pins and another for studs, unless there is a difference in the lengths of the

1. stud shanks
2. stud threads
3. pins
4. spacers

Learning Objective: Identify fundamentals of operating and caring for portable air compressors and power earth augers.

2-65. The pressure drop in air line hose over a long distance is taken care of by the installation of

1. two air compressors in series
2. two air compressors in parallel
3. an air manifold

2-66. Refer to textbook figure 4-21. Which of the following tasks should be performed on an air compressor daily?

1. Change the compressor oil
2. Grease the engine
3. Inpsect the compressor oil filter cartridges
4. Clean the radiator and cooler cores

2-67. Which of the following devices prevents the clutch from being engaged or disengaged while the air compressor engine is running?

1. Shifter mechanism
2. Electric clutch
3. Built-in safety interblock
4. Friction disk

2-68. In starting up an air compressor engine, you can eliminate the warmup steps after the first daily startup.

2-69. Which of the following is an indication that the cartridge of an air cleaner used with a Worthington air compressor needs replacement?

1. A red flag pops up
2. A green flag pops up
3. The aspirator plugs up, sounding an alarm
4. The cartridges plugs up, sounding an alarm

2-70. Which of the following is the reason for the safety statement, "Never use benzene, kerosene or other light oils to clean compressor intake filters, cylinders or air passages"?

1. They form a highly explosive mixture under compression
2. They form a gum and cause parts to wear
3. They form a varnish and will plug up fuel lines
4. They form a varnish and cause the cylinder rings to stick

2-71. Which of the following are routine prestart checkpoints for the earth auger?

1. Oil levels in the engine crankcase and transmission
2. Supply of fuel and hydraulic oil level
3. Coolant and battery water levels
4. All of the above

2-72. After cranking an auger engine for more than 30 seconds, you should wait 1 minute to allow for cooling of the

1. battery
2. starter
3. generator
4. engine oil

2-73. Refer to textbook figure 4-29. The purpose of the spirit level is to

1. level the auger engine
2. level the auger shaft
3. plumb the auger shaft
4. plumb the auger engine

2-74. Support jacks are used to dampen bouncing of the earth auger when it is being operated in hardpan or rocky soil.

Assignment 3

Test Equipment, Control and Protective Equipment

Textbook NAVEDTRA 10636-H: Pages 88-128

Learning Objective: Identify principles and techniques of measuring with an ammeter, voltmeter, megohmmeter, phase sequence indicator, and special purpose testers.

3-1. What does the accuracy of test equipment depend upon?

1. Its design
2. Your test procedures
3. The treatment of the instrument
4. Each of the above

3-2. When measuring an unknown current with an ammeter which is capable of measuring several different ranges, you should make the first measurement with the meter set at

1. the highest range it will measure
2. a range slightly higher than you estimate the current to be
3. the range where you estimate the current to be
4. the lowest range it will measure

3-3. After using the ohmmeter scale of a multimeter, what should you do to guard against dishcharging the battery in the multimeter?

1. Turn off the multimeter
2. Turn the meter to d-c supply positive
3. Turn the meter to d-c supply negative
4. All of the above

3-4. How must an ammeter be connected in the line to measure current?

1. Across the line
2. In series with the line
3. Parallel
4. Series-parallel with the load and line

3-5. The maximum current-carrying capacity of an ammeter is called its

1. polarity
2. rating
3. calibration
4. current flow

3-6. Which of the following factors would limit the current-measuring capabilities of an ammeter?

1. Size of the instrument
2. Range switch
3. Connecting terminals
4. All of the above

3-7. Why is a shunt sometimes used on an ammeter?

1. To give more accurate readings
2. To create a voltage drop
3. To extend the range of the meter
4. To calibrate frequency

3-8. Which of the following is a difference between the voltmeter and the ammeter?

1. A voltmeter has only one scale; an ammeter has more than one
2. A voltmeter can measure a-c only; an ammeter can measure both a-c and d-c
3. A voltmeter must be connected in parallel with the line; an ammeter is connected in series
4. A voltmeter must be used with a shunt; an ammeter may or may not be used with a shunt

3-9. The presence of three internal resistors in a voltmeter schematic would indicate that

1. the voltmeter is more rugged than a meter with one resistor
2. more protection is provided the meter than to one with one resistor
3. the meter could be used for three times its rated voltage
4. the meter has three voltage ranges and scales

3-10. When measuring voltage less than 600 volts and more than 100 volts, what should you do?

1. Add an external resistor to the meter
2. Add an external shunt to the meter
3. Move the meter selector switch to the highest range
4. Move the meter selector switch to the lowest range

3-11. After hooking up the clamp on voltammeter (textbook figure 5-9) to read voltage only, you can connect it to read current by clamping its jaws around one of the conductors to the motor and then turn the switch to AMPERES.

3-12. In addition to being used primarily for testing insulation, the Vibrotest megohmmeter can be used to measure

1. alternating and direct current
2. a-c and d-c voltage
3. d-c voltage only
4. power factor

3-13. You are testing a capacitor with a Vibrotest megohmmeter. Six seconds after starting the test, the needle stops moving upward. You can estimate the value of the capacitor to be

1. .04 μF
2. .4 μF
3. 4.0 μF
4. .004 μF

3-14. What is the reason for keeping records of transformer insulation tests?

1. The scheduling of further tests is made convenient
2. No change in insulation resistance indicates properly functioning equipment
3. A gradual deterioration in insulation resistance can be more easily noted
4. Technical publications recommend it

3-15. Refer to textbook figure 5-22. You are instructed to check the phase sequence of an incoming alternator and make the hookup. After connecting the phase sequence meter lead A to X_1, B to Y_1, and C to Z_1, the meter rotates in the counterclockwise direction. When you connect the meter lead A to X, B to Y, and C to Z, the meter rotates clockwise. Which of the following connections are made correct in hooking up?

1. X to X_1, Y to Y_1, Z to Z_1
2. Z to X_1, Y to Z_1, X to Y_1
3. X to Y_1, Y to X_1, Z to Z_1
4. X to Z_1, Y to X_1, Z to Y_1

3-16. The Snap-Around probe used with the Servivar Electrical Tester measures the current flowing in a conductor by means of

1. capacitive pickup
2. Direct contact
3. Heat transfer
4. Transformer action

3-17. Adapters are available which enable the Weston Model 639 Industrial Analyzer type 3 to be used for single- and three-phase, 3-wire measurements.

3-18. The chief function of the MS-1A tester is to measure the

1. amount of power used by a load at a given voltage
2. percent of the load that is shared by each phase of a three-phase power source
3. resistance of protective devices due to corroded contacts
4. time it akes a protective device to open a circuit at a given current

● In answering items 3-19 and 3-20, refer to figure 5-31 of your textbook and assume that you are testing a ground.

3-19. R_1 is adjusted until the currents in what two windings cancel each other?

1. Primary of T_1 and secondary of T_1
2. Primary of T_1 and primary of T_2
3. Primary of T_2 and secondary of T_1
4. Primary of T_2 and secondary of T_2

3-20. The unknown ground resistance is read on

1. M
2. R_1
3. V_1
4. V_2

3-21. What is the maximum permissible resistance between solid earth ground and the lightning arrester ground on a distribution system?

1. 1 ohm
2. 5 ohms
3. 10 ohms
4. 15 ohms

Learning Objective: Recognize the purpose of a Wheatstone bridge and techniques of using the bridge to measure loop resistance of a communications circuit.

3-22. The purpose of the Wheatstone bridge shown in textbook figure 5-34 is to

1. indicate the resistance of a circuit directly in ohms without any need for calculations
2. locate cable faults approximately in communication and power cables by measuring resistance in the cable wires
3. measure the magnitude of the active power in an electric circuit
4. detect the difference in potential between two points of a circuit

● In answering items 3-23 and 3-24, refer to table 5-1.

3-23. When using the Wheatstone bridge to measure a loop resistance of approximately 1,200 ohms, at what position do you set the MULTIPLY BY dial?

1. 1/100
2. 1/10
3. 1/1
4. 10/1

3-24. With the MULTIPLY BY dial on 1/1, you balance the Wheatstone bridge with a reading of 3 on the thousands dial, 8 on the hundreds dial, 3 on the tens dial, and 1 on the units dial. What is the actual resistance in the loop?

1 38.31 ohms
2. 383.31 ohms
3. 3,831. ohms
4. 38,310. ohms

3-25. When preparing to make a loop resistance test of a pair of conductors with the portable Wheatstone bridge, what connections must you make?

1. Connect the two far ends of the pair of wires together
2. Connect the cable sheath to the ground point
3. Ground one wire and connect it to binding post X_2
4. Reverse the wires connected to line binding posts X_1 and X_2.

3-26. What galvanometer indication tells you that the Wheatstone bridge is balanced?

1. Pointer movement to the left or negative side of the meter and back to zero
2. Pointer movement to the right or position side of the meter and back to zero
3. No deflection of the meter
4. A full scale deflection to either side of the meter

Learning Objective: Recognize principles and applications of the regular Varley loop test, three Varley test, and Murray loop test.

3-27. The objective of a regular Varley loop test is to locate a

1. ground in a high resistance loop when the unbalance is 1 ohm or less
2. ground in a high resistance loop when the unbalance is more than 1 ohm
3. cross in a high resistance loop when the unbalance is more than 1 ohm
4. cross in a high resistance loop when the unbalance is 1 ohm or less

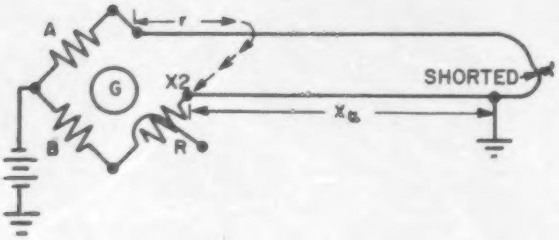


Figure 3A

- To answer items 3-28 through 3-30, refer to figure 3A and apply the formula:

$$Xa = \frac{(r \times B) - (A \times R).}{A + B}$$

3-28. Let $\frac{A}{B} = \frac{1}{1}$. Then R, the decade dial reading of the meter after the loop is balanced will equal

1. loop resistance (r) minus twice the resistance of Xa
2. loop resistance (r) minus the resistance of Xa
3. loop resistance (r) plus the resistance of Xa
4. the resistance of Xa

- In answering items 3-29 and 3-30, use the following information:

  Loop resistance = 6,020 ohms (r)
  R = 10,510 ohms
  A = 1
  B = 4
  Distance from the test set to the short circuit at the far end of the cable run is 70 miles.

3-29. What is the resistance from test point X_2 to the fault?

1. 1594 ohms
2. 2313 ohms
3. 2714 ohms
4. 3010 ohms

3-30. How far is the fault from binding post X_2?

1. 60.5 miles
2. 61.7 miles
3. 63.1 miles
4. 65.3 miles

3-31. In making a three-Varley test you set the MULTIPLY BY dial on 1/4. To obtain the resistance from the test set to the ground, you multiply the difference between the decade dial readings of the second and third tests by

1. 5
2. 8
3. 3
4. 4

- In answering items 3-32 and 3-33, refer to textbook figure 5-38 and assume that you are using a three-Varley test. You are using the 1/9 range on the MULTIPLY BY dial and you have obtained the following information:

  $R_1 = 3{,}500$
  $R_2 = 4{,}100$
  $R_3 = 9{,}600$

3-32. What is Xa?

1. 270
2. 550
3. 1250
4. 1570

3-33. If the distance to the far end of the cable run is 61 miles, what is the distance to the fault?

1. 27 miles
2. 35 miles
3. 43 miles
4. 55 miles

3-34. If you need to use A/B = 1 and the resistance in the faulty wire is greater than the good wire, what measure do you take to balance the bridge in the Varley 1 test of figure 5-38?

1. Disconnect the good wire
2. Ground the good wire
3. Put a resistance in series with the good wire
4. Use the 1/10 range on the MULTIPLY BY dial

3-35. Assume that you are using the Murray loop test shown in textbook figure 5-39 and you have set the MULTIPLY BY dial at M100. Also, assume that the length of the loop is 30 miles and you have obtained a reading of R = 1,400. Determine the distance: Da (from point X_2 to the ground).

1. 12 miles
2. 16 miles
3. 22 miles
4. 28 miles

Learning Objective: Point out the purpose of the cable repairman's test set I-51, and identify principles of locating a ground in a telephone cable.

3-36. What is the purpose of a cable repairman's test set?

1. To locate faults in PBX connectors, regular connectors, and reverting-call switches
2. To measure the magnitude of the active power in an electric circuit
3. To locate an open circuit in communication and powerlines
4. To locate accurately a short in a cable after its approximate location is determined

3-37. You know or are able to find the following information about a cable that has a fault:
A. The type of fault
B. The resistance of good conductors
C. The resistance of faulty conductors
D. Approximate location of the fault
E. Length of the cable
F. Equipment connected to the cable
Which items of information are essential in pinpointing a cable fault with the cable repairman's test set?

1. A, C, D
2. A, B, E
3. B, D, E
4. D, E, F

● Information for items 3-38 through 3-43. Refer to textbook figure 5-42. You are going to use a cable repairman's test set to pinpoint a ground in a 51-pair telephone cable that has been located with a Wheatstone bridge. The ground is solid and concerns one wire only.

3-38. Connections between the test set and the cable are made with a 2-wire test cord. Where do you connect the test cord on the cable end?

1. To the grounded conductors
2. To the grounded conductor and a ground rod
3. To the cable sheath and the grounded conductor
4. To the grounded conductor and a cable clamp

3-39. To what terminals on the test set do you connect the other ends of the test cord?

1. 1 and 3
2. 2 and 3
3. 3 and 4
4. 4 and 5

3-40. If the fault has a resistance of over 100 ohms, to what test set terminals do you connect the test cord leads?

1. 1 and 3
2. 2 and 3
3. 3 and 4
4. 3 and 5

3-41. How should you hold the exploring coil to locate the ground?

1. Parallel to the cable
2. Parallel to the cable and move it along the cable toward the grounded point
3. At right angles to the cable
4. At right angles to the cable and move it along the cable near the grounded point

3-42. When the exploring coil is right over the grounded point, the tone of your receiver

1. increases
2. disappears
3. increases then decreases
4. decreases then increases

3-43. If the ground is of such high resistance as to make the absolute location uncertain, what is the proper procedure?

1. Make a plainly visible mark at the approximate location and then repeat the tests from the other end of the cable
2. Repeat all of the tests that you made previously
3. Reset the tone switch to position 2 and repeat the tests
4. Reset the tone switch to position 2 and repeat the tests but from the opposite end of the cable

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Learning Objective: Identify principles of locating short circuits, crossed wires, and split pairs with the cable repairman's test set.

3-44. How should you locate a short in a paired cable with the cable repairman's test set?

1. Set the tone switch on position 1 and connect the test cord to the two faulty wires
2. Set the tone switch on position 2, connect the test cord to the two-faulty wires, and use the exploring coil
3. Use a test cord containing three insulated wires and connect them to three separate cable wires
4. Set the tone switch on position 2 but do not use the exploring coil

3-45. Refer to figure 5-46 in the textbook. In what way does the locating of crossed wires differ from the locating of a grounded wire in a paired cable?

1. The tone switch is set on position
2. The test cord is connected to terminals 3 and 4 on the tone unit
3. The exploring coil is held at right angles to the cable
4. The exploring coil is not used

3-46. Refer to textbook figure 5-48. In locating a split pair, what procedure must you follow at the far end of the cable that is under test?

1. Connect the two wires that are split
2. Connect the split pairs to ground
3. Short out the four wires involved
4. Disconnect the four wires involved and make sure none of them is in contact with another

3-47. For your initial tracing of a cable to locate a split pair, you have both conductors of one pair connected to the test cord leads. After you pass the exploring coil over the point locating the split pair, the volume of the tone you hear through the receiver will

1. increase only
2. decrease only
3. increase and decrease
4. be steady

3-48. In the alternate method of locating a split pair, one conductor of each pair is connected to the test cord leads. After you pass the exploring coil over the split, the volume of the steady tone you hear through the receiver will

1. increase only
2. decrease only
3. increase and decrease
4. stop momentarily, then remain steady

3-49. You are testing for a wet spot in a cable. After the exploring coil passes over the wet spot, the volume of the tone you hear through the receiver will

1. increase only
2. decrease only
3. increase or decrease
4. neither increase and decrease

3-50. There are two methods of connecting the tone unit of the test set to a cable for tracing a wet spot. In one of these methods, the two leads in the test cord are connected to

1. one wire in each of two pairs of wires
2. two groups of wire, selected at random, and strapped together
3. two wires selected at random
4. one wire, selected at random, and the cable sheath

Learning Objective: Identify procedures and techniques of locating and tracing buried communication cable with the cable repairman's test set.

3-51. You are using the cable repairman's test set I-51 and component parts necessary for tracing buried cable. How can the tone volume be increased when the exploring coil is connected directly to the receivers via a terminal strip?

1. By increasing the source voltage in the test set
2. By connecting an amplifier between the exploring coil and the receivers
3. By changing the tone switch from position 1 to position 2
4. By changing the test leads from the high resistance lugs to the low resistance lugs at the set

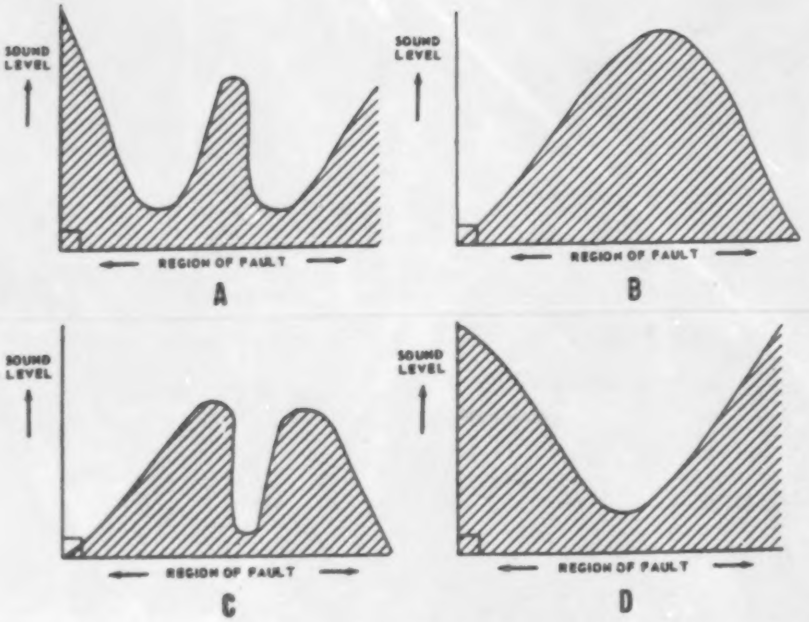

Figure 3B

3-52. You are using the stray current method of tracing a buried cable. Which of the graphs in a figure 3B illustrates the change in sound as you approach, and then pass over the cable?

1. A
2. B
3. C
4. D

3-53. The induction from a nearby powerline precludes the use of stray current to trace a buried cable. An alternate method for tracing the cable involves the use of current from a

1. ducter ohmmeter
2. power circuit analyzer
3. Wheatstone bridge
4. cable repairman's test set

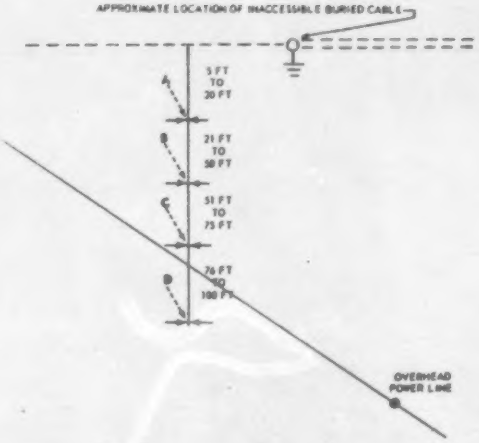
APPROXIMATE LOCATION OF INACCESSIBLE BURIED CABLE
A
5 FT TO 20 FT
B
21 FT TO 50 FT
C
51 FT TO 75 FT
D
76 FT TO 100 FT
OVERHEAD POWER LINE

Figure 3C

3-54. At which point should the nearest ground rod be located from the buried cable in figure 3C?

1. A
2. B
3. C
4. D

3-55. While attempting to locate the vicinity of a buried cable with test set I-51, you should start by holding the exploring coil in what position?

1. Horizontal and parallel to the cable
2. Vertical and parallel to the cable
3. Perpendicular to the cable

3-56. Assume that you have found the general location of a cable with test set I-51. What type of tone will indicate the exact location of the cable if the exploring coil is held in the horizontal position and passed over the cable?

1. A steady rise in tone until maximum tone is received
2. A steady rise in tone and then a sharp decrease in tone
3. A tone that changes from constant to pulsating
4. A tone that changes from low pulsating to high constant

Learning Objective: Identify operating principles and techniques of the telephone test set AN/PTM-5 and the Tela Cable Model 262 test set.

3-57. The purpose of the telephone test set (AN/PTM-5) is to

1. identify single leads or pairs in a cable without breaking the individual conductor insulation
2. identify single leads or pairs in a cable without breaking or opening the outer sheath
3. locate open or shorted leads in a cable without breaking individual conductor insulation
4. locate open or shorted leads in a cable without disturbing the position of the conductors

3-58. In what position should the probe tip be held when you are checking conductor pairs with the telephone test set?

1. Between the pair, nearly parallel to the conductors
2. Between the pair, at right angles to the conductors
3. Across the pair, at right angles to the conductors
4. Squeezed tightly against the pair with the fingers

3-59. How are grounds indicated on the Tela Cable Model 262?

1. Shorted light goes out
2. Indicating light comes on
3. Indicating light flashes
4. Shorted light flashes

3-60. Before identifying a certain wire in a cable with a Tela Cable test set, an operator must have

1. an assistant standing by to deenergize the circuit
2. an assistant at the point where the cable is terminated
3. the circuit energized
4. the circuit deenergized

Learning Objective: State the purpose of electrical protective devices and indicate techniques of locating common faults in fused circuits.

3-61. The purpose of electrical protective devices is to

1. govern the amount of power delivered to any electrical load
2. prevent power interruptions
3. prevent short circuits
4. prevent dangerous amounts of power in a circuit

3-62. In locating the cause of trouble in a defective circuit, the first thing you should do is to

1. test the circuit with a voltage tester
2. trace the wiring
3. disconnect the black and white wires from the source of power
4. check the circuit for visible signs of trouble

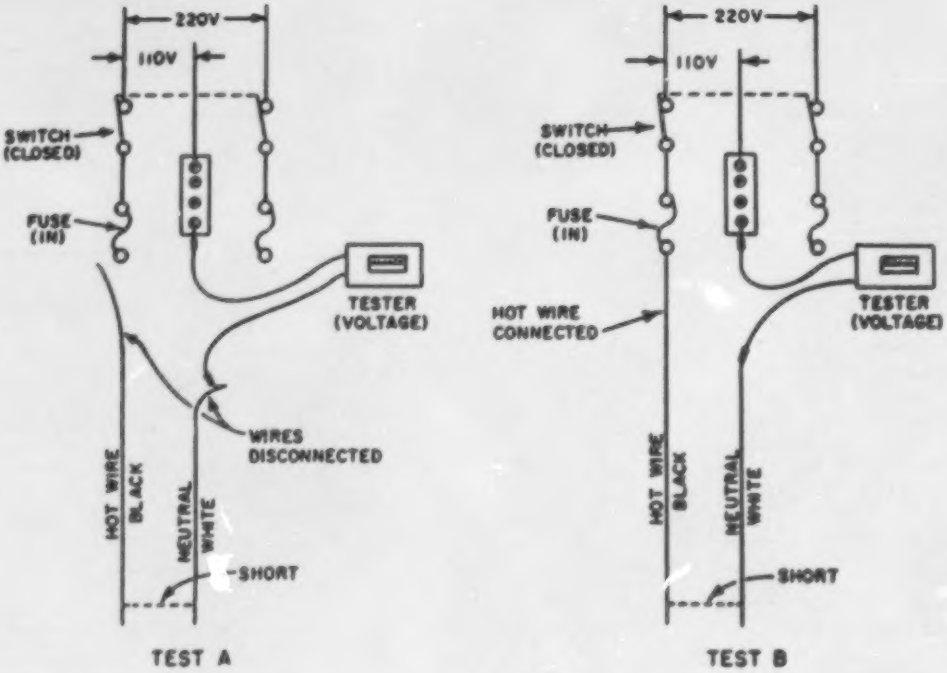
220V
110V
SWITCH (CLOSED)
FUSE (IN)
TESTER (VOLTAGE)
WIRES DISCONNECTED
HOT WIRE BLACK
NEUTRAL WHITE
SHORT
TEST A
220V
110V
SWITCH (CLOSED)
FUSE (IN)
TESTER (VOLTAGE)
HOT WIRE CONNECTED
HOT WIRE BLACK
NEUTRAL WHITE
SHORT
TEST B

Figure 3D

3-63. Figure 3D illustrates how you can use a voltage tester to test for a short circuit. The circuit has a short if the tester shows

1. a reading when you make test A
2. a reading when you make test B
3. readings when you make tests A and B
4. no readings when you make test A or B

● When answering 3-64 and 3-65, assume that now you are trying to locate a fault in a single-phase 2-wire circuit.

3-64. Before you begin any work on the circuit, you must make sure that

1. the switch is opened and all fuses are removed
2. the hot wire is disconnected at the fuse box when an open circuit is suspected
3. the hot wire is disconnected at the fuse box when a short circuit is suspected
4. both wires are disconnected at the fuse box

3-65. In disconnecting and connecting the wires from the terminals in the fuse box, you should disconnect the

1. hot wire first and connect it first
2. neutral wire first and connect it first
3. neutral wire first and connect the hot wire first
4. hot wire first and connect the neutral wire first

Learning Objective: Recognize operating principles and applications of fuses and circuit breakers.

3-66. What components in a substation, in addition to feeder line breakers, protect transmission lines from the effects of short circuits?

1. Low voltage feeder breakers
2. Low voltage feeder fuses
3. High voltage circuit breakers
4. High voltage fuses

3-67. Fuses combined with gang-operated air-break switches are safe to use with transformers having a capacity of

1. 3,750 kVA
2. 6,000 kVA
3. 7,500 kVA
4. 10,000 kVA

3-68. What action takes place in or is initiated by an expulsion type primary cutout fuse when a serious overload occurs?

1. A second fuse is cut into the circuit
2. A high resistance is placed in series with the load
3. The fuse resets itself
4. The fuse link melts and opens the circuit

3-69. Suppose that in an automatic reset repeating cutout, the first and second fuses blow but the third fuse does not. There is reason to believe that this situation was caused by a

1. short circuit in one of the distribution transformers
2. permanent open in the transmission line
3. temporary fault in the distribution system
4. source generator with an excessive voltage output

3-70. Oxidation on a fuse or fuse clip is an indication of poor contact between the fuse and fuse clip.

3-71. Sections of electrical circuits in substations are often conveniently made safe to work on by

1. installing circuit breakers at important wire junctions
2. placing several more generators than are needed in the substation
3. installing all circuit cables in parallel
4. placing the high voltage circuits underground

3-72. What causes an electrically operated air circuit breaker to open when an excessive current flows through it?

1. A fusible link melts, causing a coiled spring to open the contacts
2. An electromagnet forces the contacts open
3. An electromagnet trips a release mechanism allowing a coiled spring to push the contacts open
4. Current through a high tension spring causes it to expand and open the contacts

3-73. The main contacts of high current circuit breakers are not burned when they open or close due to the

1. bypass action of the arc contacts
2. quenching action of the arc quencher section
3. actions of the bypass contacts and the arc quencher section
4. magnetic field which flows under the arc runner

Assignment 4

Control and Protective Equipment

Textbook NAVEDTRA 10636-H: Pages 128-174

Learning Objective: Indicate procedure for maintaining and inspecting power circuit breakers.

4-1. What must you do before servicing a circuit breaker?

1. Wipe off the surface of the circuit breaker mechanism
2. Direct air from an airhose in order to remove dirt or dust from the mechanism
3. Deenergize all circuits including control circuits to which the breaker is connected
4. Look for corrosion of pins and bearings

4-2. Before working on fixed-mounted circuit breakers, what switches should you open?

1. All switches in the entire switchboard circuit
2. All generator circuit breakers
3. All switches ahead of the breakers
4. All bus tie switches

4-3. Assume that inspection of copper circuit breaker contacts reveals a blackened surface. What is the correct maintenance procedures for these contacts?

1. Wipe the black copper oxide off the contacts with a clean cloth
2. Sand the contact surfaces with fine sandpaper
3. Wipe the contact surfaces with inhibited methyl chloroform
4. Each of the above, if necessary

4-4. Which of the following is most likely to cause a relay magnet to chatter?

1. Burned contacts
2. Open coils
3. Rusty magnet sealing surfaces
4. Shorted coils

4-5. When manually operated circuit breakers normally remain in an open or clogged position over a long period, how often should they be tested?

1. Twice a year, or more often
2. Once each year
3. Once every 2 years
4. Once every 5 years

4-6. Assume that you installed a circuit breaker in the spring of last year. Its first overhaul is due no later than

1. spring of this year
2. fall of this year
3. spring of next year
4. fall of next year

4-7. The first thing that you must do before overhauling a circuit breaker that is in use is to

1. ground the equipment
2. remove all fuses
3. warn people who are using the circuit
4. notify the electrical supervisor of your plans

4-8. Your are cautioned NOT to trip the contact mechanism of an oil circuit breaker after the contacts are lifted from the oil in order to

1. facilitate the finding of damaged parts
2. minimize the possibility of rust forming on the contacts
3. avoid electrical shock
4. prevent mechanical shock damage to breaker parts

4-9. If paper tank liners in oil circuit breakers have absorbed moisture, the liners should be dried by

1. baking them in an oven
2. placing them in the sunshine
3. blowing air on them with a fan
4. storing them in a cool room

4-10. How can the CE tell when the thickness of a circuit breaker contact has fallen below the required minimum?

1. By consulting minimum contact thickness tables in the manufacturer's instructions
2. By taking 1/2 of the original thickness as stated in the manufacturer's instructions
3. By applying a general rule tying replacement to years of usage
4. By using the figures stamped on the breaker frame

4-11. What type of contacts do radial-blast interrupters have?

1. Arcing
2. Rolling
3. Butt
4. Sliding

4-12. How much metal can be burned off contacts or radial-blast interrupters before it becomes necessary to replace them?

1. 1/32 in.
2. 1/16 in.
3. 3/32 in.
4. 1/8 in.

4-13. The usual maintenance for the main contacts of cross-blast interrupters consists of

1. applying a light coat of oil to the contacts
2. replacing damaged contacts
3. cleaning and aligning contacts
4. turning the contacts slightly to expose a new surface

4-14. The arc contacts of a power circuit breaker should be replaced when they become

1. badly pitted or burned
2. slightly discolored
3. brittle
4. bent

4-15. Which of the following is an acceptable method of determining the condition of arc contacts in power circuit breakers?

1. Remove the arc chutes and observe the condition of the arc contacts
2. Without removing any part of the breaker, observe the arc contacts with a dentist's mirror
3. Disassemble the entire breaker and observe the arc contacts
4. Observe the condition of the arcing tips and assume that the condition of the internal contacts is the same

4-16. How often is it recommended that oil in oil circuit breakers be tested?

1. Every 3 months
2. Twice each year
3. Annually
4. Every 3 years

4-17. The oil in power circuit breakers must be filtered until the oil has a minimum dielectric strength of

1. 18,000 V
2. 22,000 V
3. 26,000 V
4. 30,000 V

4-18. When oil from circuit breakers is being tested for dielectric strength, the spacing between standard disks in the tester should be

1. 0.01 in.
2. 0.10 in.
3. 0.15 in.
4. 0.20 in.

4-19. You are checking the condition of the oil in power circuit breakers. Which of the following signs is an indication that the oil must be filtered and tested for dielectric strength?

1. Carbonization
2. Dirt
3. Moisture
4. Each of the above

4-20. The recommended agent for cleaning external surfaces of power circuit breaker bushings is

1. a dry rag
2. soapy water
3. oil
4. an emery cloth

4-21. What cleaning agent is recommended for removing dust and carbon inside a magnetic airblast circuit breaker?

1. A dry rag
2. Soapy water
3. Oil
4. An emery cloth

4-22. What is the recommended method of preventing moisture from collecting in a magnet airblast circuit breaker?

1. Wiping dry with a rag frequently
2. Cleaning with a solvent regularly
3. Installing air blowers in the breaker compartment
4. Installing heaters in the breaker compartment

4-23. What is the recommended maintenance for treating burned contacts of large trip coils in oil circuit breakers?

1. Replacing the contacts
2. Readjusting the contact airgap
3. Reducing the current through the contacts
4. Cleaning with fine sandpaper

4-24. The speed of the closing motor of an oil circuit breaker is varied by means of

1. an auxiliary control breaker
2. a variable line switch
3. a variable resistor
4. a variable inductance coil

4-25. Infrequent operation is a cause of contacts overheating in power circuit breakers. One way to overcome the overheating problem is by

1. replacing the breaker with another having a large current rating
2. reducing the operating voltage to the contact relay
3. adjusting the closing relay
4. replacing copper contacts with new silver-to-silver contacts

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Learning Objective: Identify operating principles of magnetic and thermal overload relays.

4-26. What is the best recommended method of overcoming burnout of the operating coil of electrically operated breakers caused by an operator holding the control switch closed too long?

1. Lubricating the mechanism
2. Installing an auxiliary switch
3. Replacing the damaged coil
4. Putting a sign on the switch to remind the operator

4-27. Which of the following actions should you take to remedy the failure of an a-c controlled power circuit breaker to latch closed?

1. Adjust closing relay
2. Test rectifier
3. Install larger incoming wire
4. Charge battery

4-28. When an overload occurs in a magnetic type relay, the increased flux around the coil will lift the iron plunger into the center of the coil.

4-29. The current at which a magnetic overload relay trips may be increased by

1. lowering the dashpot
2. raising the dashpot
3. adding oil to the dashpot

4-30. A thermal overload relay will finally open the contacts when the

1. heater coil reaches a specific temperature
2. splitter arm moves
3. solder melts
4. tube assembly rotates

4-31. A thermal overload relay is adjusted to trip at a predetermined value of overload current by

1. changing the relative position of the contacts
2. raising and lowering the dashpot
3. rotating the splitter arm
4. moving the relay heater coil

Learning Objective: Identify fundamentals of operation of phase-failure and reverse-current relays and principles of grounding.

4-32. When two or more d-c generators are connected in parallel, what device is used to disconnect a generator from the line if the generator starts drawing power from the line?

1. Thermal type relay
2. Reverse-current relay
3. Magnetic type relay
4. Reverse power relay

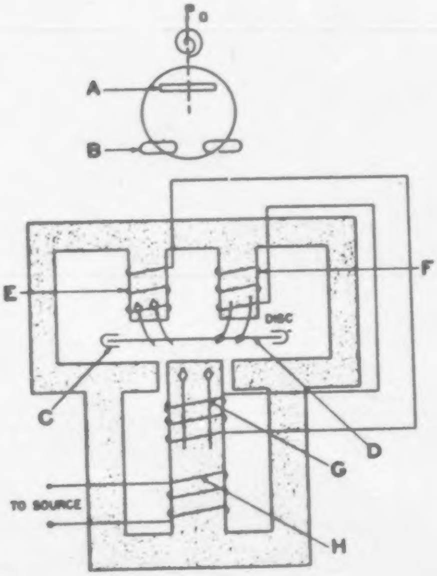


Figure 4-A

In answering items 4-33 and 4-35, refer to figure 4A.

4-33. Oscillations in the induction disk of the timer element of the relay are damped by

1. A
2. B
3. D
4. E

4-34. What must take place to cause reverse rotation of the disk?

1. The polarity of coil G must reverse with respect to the polarity of coil H
2. The polarity of coil E must reverse with respect to the polarity of coil F
3. The current through coils G and H must reverse with respect to the polarity of coils E and F
4. The current through coils E and F must reverse with respect to the polarity of coil H

4-35. The phase-failure relay is actuated when

1. current in the d-c relay coils exceeds current in the reactor coils
2. current in any one of the d-c relay coils is less than in any of the other coils
3. current in one pair of d-c relay coils is less than current in another pair
4. current is reversed through any of the rectifier bridge units

4-36. What is the basic difference, if any, between a system ground and an equipment ground?

1. System ground is the grounding of non-current-carrying metal parts while equipment grounding is the grounding of the hot side of the equipment
2. System ground is the grounding of one of the current-carrying conductors and equipment ground is the grounding of noncurrent-carrying metal parts of a wiring system
3. There is no difference except equipment ground protects personnel and system ground protects equipment
4. There is no difference; both grounds are designed to protect personnel

4-37. NAVFAC requires grounds to be provided in accordance with the National Electrical Code except that individual transformer and lightning arrestor grounds must not be above 10 ohms to ground.

Learning Objective: Recognize fundamentals of operating, maintaining, and repairing motor controllers.

4-38. What is meant by the term "plugging" as it is used in describing controllers?

1. Preventing overheating of motors
2. Starting or stopping motors
3. Increasing motor speed
4. Reversing the direction of motor fields

4-39. A sentinel breaker is comprised of which of the following components?

1. A trip switch and fuses
2. A switch and a circuit breaker
3. A bimetallic thermal element
4. A circuit breaker and a thermal element

4-40. The primary function of controllers is to protect against

1. overload
2. overload and low voltage
3. overlaod and high voltage
4. low voltage

4-41. In the single-phase pushbutton across-the-line starter discussed in the text, the main contacts are closed by the

1. latching relay
2. magnetic coil
3. holding contact
4. thermal relay

4-42. What part prevents the main contacts of a 3-phase magnetic across-the-line starter from closing while the starter is deenergized?

1. An electrical switch which opens
2. An antishock lever
3. A switch behind the stop button on the stop-start station
4. A mechanical latch, operated by a latching relay

4-43. In a 3-phase magnetic across-the-line starter, what part causes the overload relay contacts to open?

1. Start-stop station
2. Operating coil
3. Heating element
4. Holding contact

4-44. In a primary resistor controller, what path does current to the motor take after the line contactor closes?

1. Through parallel circuits consisting of the starting resistor and the accelerating contacts
2. Through series circuits consisting of the starting resistors and the accelerating contacts
3. Through the line contactor directly to the motor
4. Through the main line contacts and the starting resistors

4-45. If a wound rotor motor utilizes a secondary resistor controller, the motor is brought up to full running speed by using

1. less and less resistance in the line by steps until the motor is running full speed
2. resistance in parallel across the lines to reduce the voltage until the motor is running full speed
3. the main contacts in parallel with the starting resistors
4. a circuit like the one in a primary resistor controller but without accelerating contacts

To answer items 4-46 and 4-47, refer to figure 6-10 of your textbook.

4-46. Which of the following conditions of the F and R contactors causes line contacts R1, R2, and R3 to close?

1. F_A open
2. F_A closed
3. R_A open
4. R_A closed

4-47. The F and R contactors are prevented from both being closed at the same time by

1. a mechanical interlock
2. a 10-ampere control fuse
3. the F and R contactor coils
4. the overload relays

4-48. One advantage of an autotransformer starter is that

1. the motor is connected to the line voltage at all times
2. it utilizes capacitors and transformers in parallel to raise starting current
3. high starting line currents can be reduced more than with resistor starters
4. it can be utilized for starting loads that are heavy enough to require resistor starters

4-49. With an autotransformer starter, no energy is lost through heat because

1. transformers are used as a voltage reducing device
2. resistors are used to limit current
3. capacitors are used as a voltage buildup device
4. both transformers and capacitors are used to control voltage and current

In answering items 4-50 through 4-52, refer to figure 6-26 in the textbook.

4-50. After starting coil MS is energized, contacts MS1, MS2, MS3, and MS4 close to

1. complete the holding circuit to the starting coil
2. complete the circuit to the timer relay
3. connect the autotransformer in open delta across the line
4. connect the coil of the motor running contactor in series with the holding circuit

4-51. What contact acts as an electrical interlock and prevents coil MR from being energized when MS is operated?

1. CR1
2. CR2
3. MS6
4. MS7

4-52. MR4 is an electrical interlock that opens to

1. disconnect the transformer from the circuit
2. prevent the starting coil MS from being energized when the motor is connected directly across the line
3. open the holding coil circuit to the main starting coil
4. prevent contact CR3 from closing when the running contactor coil MR is being energized

4-53. How does controller star delta starting of a motor result in first applying 57.7 percent and later 100 percent of line voltage to the motor?

1. Relays cut two different values of resistance into the line leads
2. A star connection is tied to a delta connection in the controller
3. The motor is started on a delta winding connection and later is changed to star connection
4. Windings of a motor having delta connections are changed to star connections at first and later back to delta connection

4-54. Which of the following restrictions is placed upon the use or installation of controller cabinets?

1. They may not be used for other than motor and controller circuits
2. They may not be mounted within three feet of the motors they control
3. They must be painted a certain shade of blue
4. They need not be grounded separately

4-55. Which of the following tools or agents must NOT be used to clean controller parts?

1. Stiff brush
2. Vacuum cleaner
3. Approved solvent
4. Carbon tetrachloride

4-56. The most common cause of controller contacts' welding together is

1. dirty contacts
2. weak springs
3. high current
4. low voltage

4-57. A type of controller contact recommended for overcoming frequent welding of contacts is the

1. butt contact
2. knife blade contact
3. silver contact
4. carbon contact

4-58. A type of contact used on heavy duty controller equipment that remains closed for extended periods is the

1. silver contact
2. copper contact
3. carbon contact
4. aluminmum contact

4-59. The minimum value of controller contacts falls within the range of

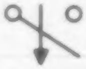
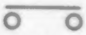
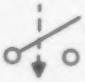
1. 0.015 to 0.020 in.
2. 0.015 to 0.030 in.
3. 0.020 to 0.030 in.
4. 0.020 to 0.040 in.

4-60. Wet controller magnet coils should be dried out by

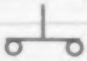
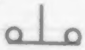
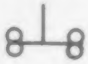
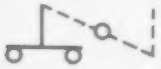
1. baking them in an oven
2. standing them in a warm room
3. sending current through them
4. letting them lie in the sunshine or under a sun lamp

Learning Objective: Identify symbols for manually and electrically operated switches.

4-61. Which of the following symbols represents a switch that is closed by a timing device?

1. 
2. 
3. 
4. Each of the above

4-62. Which of the following symbols represents a pushbutton switch whose only function is to deenergize a circuit when the pushbutton is held down?

1. 
2. 
3. 
4. 

Learning Objective: Identify operating principles of photoelectric control relays, limit switches, pressure-and temperature actuated switches, and automatic boiler controls.

4-63. The phototube type of light sensitive cell generates enough energy to operate the photocell relay directly.

4-64. A self-generating photronic cell should operate within what limits of current to be a useful control device for street lighting?

1. 2 to 6 mA
2. 2 to 6 A
3. 1 1/2 to 6 mA
4. 1/2 to 6 mA

4-65. Why are limit switches used in a circuit?

1. To ensure that the equipment operator is within safe physical limits
2. To prevent overloading of the motor circuit
3. To prevent overloading of the control circuit
4. To ensure proper operation of equipment within safe electrical limits

4-66. To actuate the contact mechanisms, bellows-type, temperature-actuated switches depend on

1. expansion of metal in the bellows
2. expansion of gas or vapor in the sensing bulb
3. expansion of gas or vapor in the bellows
4. pressure on the helical tube

4-67. Assume that a pressure switch closes at 300 psi and opens at 50 psi. After you make certain adjustments, the switch closes at 350 psi and opens at 50 psi. What kind or kinds of adjustments did you make?

1. Range only
2. Differential only
3. Temperature
4. Range and differential

4-68. To ensure accurate adjustment of thermal switches, it is necessary to

1. compensate for different rates of temperature changes
2. allow a minute or two for the unit to reach the temperature of the surrounding air, gas, or liquid
3. make adjustments very slowly while the switch is in operation
4. check operation of the switch through an entire cycle after making the initial adjustment

4-69. A change in the water level caused by an imbalance of fluid flowing into and out of the steam generating equipment is detected by a level control or float control which causes other devices to either restore the balance or cut off the fuel supply.

4-70. Basically, the purpose of the pressuretrol switch is to

1. limit the amount of water pressure generated in the boiler tubes thereby cutting off the supply of water from the pumps
2. limit the steam pressure produced by controlling the firing cycle of the burner
3. adjust the pressure screw actuating the bellows that work against the differential adjusting spring
4. react directly to the water pressure generated by the pumps by cutting off the current to them when the proper pressure is reached

4-71. Basically, the stack switch consists of a bimetal helix, a mounting frame, an electrical switch, and a

1. slotted stop plate and guide
2. mounting bracket with accompanying screws and washers
3. shaft carrying a contact-making mechanism
4. combined "break" contact and shaft

4-72. The photoelectric combustion control commonly works on the principle that the

1. cell's signal to the relay is reduced
2. relay when properly activated closes the circuit to the burner
3. relay when properly activated opens the circuit to the burner
4. burning flame's luminosity amplifies the cell's signal to make contact within the cell which, in turn, operates the relay

4-73. Which of the following electrical devices has the same function as the photoelectric combustion control?

1. Photoconductive combustion control
2. Pressure limit switch
3. Protectorelay
4. Pyrostat

4-74. Why is the protectorelay used as an electromagnetic switch on many firetube type boilers?

1. To tie together the burner operating controls and the safety combustion controls
2. To provide an interlock between the burner and burner controls
3. To cause emergency shutdown of the burner in response to safety combustion controls
4. To perform all of the above

Assignment 5

Shopwork

Textbook NAVEDTRA 10636-H: Pages 175-222

Identify principles of organizing an electrical shop and distinguish between good and poor shop practices.

5-1. The electrical repair shop should NOT be used as a

1. general headquarters for repair and maintenance of electrical equipment
2. storeroom for electrical parts for repair of equipment
3. storage depot for the conduit and wire to be used in new construction on the jobsite
4. storeroom and issue room for tools used for electrical equipment repair and maintenance

5-2. When a shopman receives repair parts, such as ball bearing assemblies, he should make it a practice to

1. place them in storage without disturbing their wrappers
2. inspect them to ensure they are of the proper size and in good condition, then store them
3. inspect the, treat with preservative, and then store
4. store them near the euipment on which they may be needed

● To answer items 5-3 through 5-6, determine whether an item describes a good shop practice or a poor shop practice. Erase block 1 on the answer sheet to indicate a good practice; erase block 2 to indicate a poor practice.

5-3. To keep from damaging repair parts, you leave them in their original containers until ready to use.

5-4. When mixing an electrolyte, you pour the acid into the water.

5-5. You wear gloves on both hands when filling a blowtorch with fuel.

5-6. Before starting to work around a rotating machine, you remove your finger rings and wrist watch.

5-7. All Navy installations must ground some appliances. Local authorities may decide not to ground others. The supply voltage that represents the division between the two classes of appliances is

1. 50 v
2. 100 v
3. 150 v
4. 200 v

5-8. Which of the following electrical appliances must have their cases or enclosures grounded?

1. Food mixers
2. Record players
3. Soldering irons
4. All of the above

Learning Objective: Recognize techniques of disassembling a generator or motor and repairing commutators and collector rings.

5-9. Assume that you are sent out to a substation to repair a 3-phase a-c generator that is inoperative. To save yourself time and labor, your first effort toward repairing the generator should be to explore the possibility that the source of the trouble is a

1. sudden change of atmospheric conditions
2. defective manufactured part
3. neglected routine maintenance action
4. poor housekeeping habit

5-10. In breaking down an a-c generator into its component parts, you should use a rawhide or rubber mallet in order to

1. withdraw the rotor
2. work the end bells out of the frame
3. mark the end bells and the frame
4. remove the bolts holding the end bells in place

5-11. After removing semisealed ball bearings from motor end bells, which of the following actions should you take?

1. Use an approved cleaning solvent on the bearings before storing them
2. Store the bearings in a piece of clean waxed paper until they are ready to be reinstalled
3. Be careful to apply pressure only to the outer race
4. Each of the above

5-12. You should wear canvas gloves when removing a rotor from a generator to prevent the keyways from

1. scratching the field coils
2. nicking the pole pieces
3. scoring the commutator bars
4. cutting your fingers

5-13. A blue or green discoloration on the copper surfaces of a commutator should be removed with a

1. grinding resurfacer
2. dressing tool
3. lintfree cloth dipped in approved solvent
4. strip of canvas moistened with light oil

5-14. What step should you take just before resurfacing pitted collector rings with a commutator stone dressing tool?

1. Clean the collector rings with a solvent
2. Polish the collector rings with oiled canvas
3. Let the generator cool off
4. Run the generator under load

5-15. When turning a commutator on a lathe, how can you keep from twisting the bars?

1. Use a cutting depth of 0.01 inch or less
2. Run the lathe slower than the rated speed of the generator
3. Run the lathe faster than the rated speed of the generator
4. Use a feed of 0.10 ipm

5-16. Which of the following tools should you use to remove any insulating mica that protrudes from slots between commutator bars?

1. A power-driven flexible-shaft undercutter
2. A slotting tool
3. A cutter improvised from a hacksaw blade
4. Each of the above

5-17. When measuring the air gap at the commutator poles to determine the amount of commutator wear or misalinement, how many points of reference should you measure on the stator with respect to a single reference point on the rotor?

1. Five
2. Two
3. Three
4. Four

5-18. The surface of a commutator can be cleaned with a

1. canvas wiper only
2. canvas wiper or a toothbrush
3. toothbrush or a strip of fine sandpaper
4. strip of fine sandpaper or a canvas wiper

5-19. Pitting caused by electrolytic action on the surface of collector rings can be prevented by

1. reversing the polarity of the rings every few days
2. changing the brushes every few days
3. checking the rings often and changing them when they become worn
4. polishing the rings with a crocus cloth

Learning Objective: Identify practices in maintaining and replacing brushes on d-c motors and generators.

5-20. The grade of brush used in a motor or generator is determined by the

1. size of the motor or generator
2. load and speed of the motor or generator
3. time in service

5-21. Brushes should be replaced when they are worn to within

1. 1/8 inch of the metallic part, or more than 75 percent of the original length of the brush
2. 1/8 inch of the metallic part, or more than 50 percent of the original length of the brush
3. 1/4 inch of the metallic part, or more than 75 percent of the original length of the brush
4. 1/4 inch of the metallic part, or more than 50 percent of the original length of the brush

5-22. You can calculate brush pressure by

1. dividing the brush contact area by the spring pressure
2. subtracting brush contact area from the spring pressure
3. dividing the spring pressure by the brush contact area
4. subtracting the spring pressure from the brush contact area

5-23. When seating a brush, you should use a brush seater and

1. emery paper
2. a file
3. sandpaper
4. an oilstone

5-24. When seating a brush, you should place the sandpaper between the brush and the commutator with the rough side toward the

1. commutator and pull the sandpaper in the opposite direction of normal commutator rotation
2. commutator and pull the sandpaper in the direction of normal commutator rotation
3. brush and pull the sandpaper in the opposite direction of normal commutator rotation
4. brush and pull the sandpaper in the direction of normal commutator rotation

5-25. The finishing steps you take to complete the job of seating the motor brush include

1. turning the sandpaper over, sandpapering again, and touching the seater to the heel of the brush for a second or two
2. touching the seater to the commutator for one or two seconds, vacuuming the dust that results, and cleaning the commutator
3. lifting the brush, inserting the seater between brush and commutator for a second or two, and cleaning the commutator
4. pulling a finer strip of sandpaper between brush and commutator once or twice, vacuuming the dust that results, and cleaning the commutator

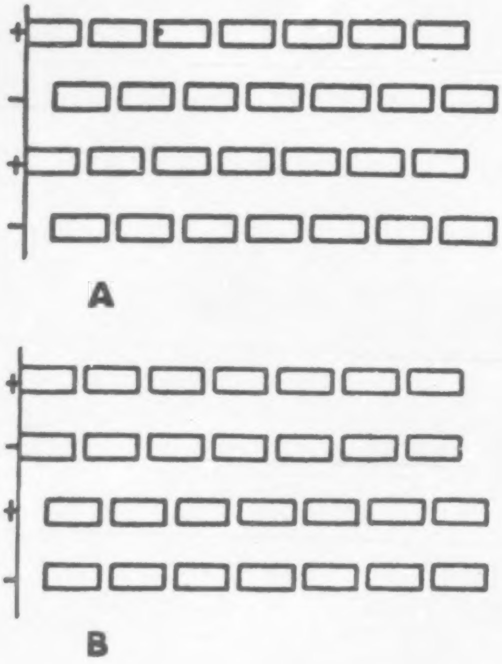


Figure 5A

5-26. Are the brushes in A and B of figure 5A staggered correctly or incorrectly?

1. The brushes in both A and B are staggered correctly
2. The brushes in both A and B are staggered incorrectly
3. The brushes in A are staggered correctly, but the brushes in B are staggered incorrectly
4. The brushes in A are staggered incorrectly, but the brushes in B are staggered correctly

5-27. Brushes may be set on the no-load neutral point of a commutator by the mechanical method or by the reversed rotation method. In either method the brushes are positioned on the commutator at a point where minimum voltage is induced between the

1. adjacent commutator bars
2. commutator and main-field pole
3. commutator and armature
4. commutator and windings

Learning Objective: Identify principles and practices in the maintenance and repair of generator or motor ball bearings and armatures.

5-28. The type of bearing used in motor construction is primarily thrust or radial, depending mainly on whether the

1. rotor rotates clockwise or counterclockwise
2. motor is mounted vertically or horizontally
3. drain holes on the bearing housing are accessible or not
4. bearing housing is, or is not, disassembled to renew bearing grease

5-29. Watch personnel should be familiar with the normal operating temperature of generator bearings in order to detect any sudden change in bearing oil temperature.

5-30. When pressing a bearing onto a shaft, you must apply pressure to what part of the bearing?

1. Cage
2. Raceway
3. Inner ring
4. Outer ring

5-31. What kind of solder do you use for soldering banding wire?

1. Pure lead solder
2. Pure tin solder
3. Lead-alloy solder
4. Tin-alloy solder

5-32. One method of determining what type of winding an armature has is to measure the variations in the resistance found at different places around the commutator. You can read this difference on a low-reading ohmmeter or use a milliammeter connected

1. parallel with a rheostat and a 6-volt battery
2. parallel with a rheostat and a 12-volt battery
3. in series with a rheostat and a 6-volt battery
4. in series with a rheostat and a 12-volt battery

5-33. On a simplex wave winding the maximum ammeter reading will be indicated when the probes are placed on commutator segments that are approximately how far apart?

1. One pole pitch
2. Two pole pitches
3. Three pole pitches
4. Four pole pitches

5-34. Blue sparks that pass around the armature of a running machine indicate an open armature coil. The sparking occurs because, as the segment to which the open coil is attached passes under a brush, the brush

1. opens and closes a circuit
2. burns the coil insulation
3. shorts out the coil
4. grounds the coil

5-35. In the bar-to-bar test, measurements are taken with which of the following instruments?

1. Milliammeter
2. Millivoltmeter
3. Ohmmeter
4. Each of the above

5-36. Which of the following voltmeter readings indicates a real ground in a d-c armature?

1. Low voltage before and after rotation of the armature
2. Low voltage before rotation of the armature, and normal voltage after rotation
3. Normal voltage before rotation of the armature, and low voltage after rotation
4. Normal voltage before and after rotation of the armature

5-37. How will the voltmeter in textbook figure 7-30 read for open simplex armature coils and for shorted simplex armature coils?

1. Minimum for both open and shorted coils
2. Maximum for both open and shorted coils
3. Minimum for open coils and maximum for shorted coils
4. Maximum for open coils and minimum for shorted coils

5-38. Assume that the test shown in textbook figure 7-30 reveals voltmeter readings that increase or decrease and are alternately positive and negative. What is indicated by such readings?

1. A short in a simplex winding
2. A short in a duplex winding
3. An open in a simplex winding
4. An open in a duplex winding

5-39. During a growler test, you hold a hacksaw blade directly over the top slot of the armature to test for a/an

1. grounded coil
2. shorted coil
3. opened coil

5-40. Assume that you are making emergency repairs to a d-c motor that has a short-circuited armature coil. In order to keep the motor in service until the coil can be replaced you will have to

1. disconnect the coil at one end only
2. cut the coil at one end, then install jumper between this end and the other end of the coil
3. cut the coil at both ends and install a jumper between the risers from which the coil was disconnected

5-41. Before stripping an armature you must record the initial winding data. After recording the data, your next step is to

1. disconnect and remove the coils
2. perform a bar-to-bar test to determine what type winding it has
3. remove the banding wires
4. unsolder the coil leads from the commutator

5-42. The armature wiring should be tested for grounds, opens, or shorts after the coil ends are soldered to the commutator segments.

5-43. When do you put shrink rings on a commutator?

1. After the armature has been baked
2. Before the armature has been baked
3. After the commutator has been tightened
4. Before the commutator has been tightened

- In answering items 5-44 and 5-45, refer to textbook table 7-2.

5-44. Silk immersed in oil can be used as insulation on what class of insulation system?

1. A
2. B
3. F
4. H

5-45. What classes of insulation material are considered fragile and should be handled with care?

1. B and F
2. F and H
3. H and N
4. B and N

5-46. The maximum number of times that the windings should be dipped and baked during varnishing is

1. five
2. two
3. three
4. four

5-47. Refer to textbook table 7-3. A high-potential test can be made on a d-c generator when the rewinding is complete and the insulation resistance has been measured and found to be higher than 1 megohm in the

1. armature alone
2. armature circuit less the armature
3. complete armature circuit
4. complete shunt field circuit

5-48. In performing the high-potential test you maintain the full voltage required for 1 minute. Then you should reduce the voltage to one-quarter of the correct value within

1. 10 seconds
2. 15 seconds
3. 20 seconds
4. 25 seconds

Learning Objective: Indicate principles of troubleshooting field coils and stator coils.

5-49. An open circuit in the field winding of a d-c generator that is carrying a load will be indicated by

1. excessive armature current
2. heavy sparking
3. loss of load and voltage
4. stalling of the generator

5-50. Coils are classified as shunt field coils or series and commutating field coils, with one difference being that the former consists of many turns of fine wire while the latter consists of few turns of heavy wire.

5-51. You can discover and locate an open a-c stator winding by taking resistance readings of the

1. coil ends
2. phase terminals
3. interpoles
4. phase terminals, then the coil ends

5-52. After you have rewound stator coils and taped them with insulation, you tin the free ends of each coil. Your next step is to test for

1. continuity and grounds
2. shorted turns and grounds
3. continuity and shorted turns

5-53. The trouble that shorts an entire pole-phase group can be readily located by means of

1. an ammeter
2. an ohmmeter
3. a compass test
4. a balanced-current test

5-54. The balanced-current test is made with

1. an industrial analyzer
2. a low voltage d-c source
3. an ohmmeter

Learning Objective: Identify principles and techniques of maintaining motors and generators.

5-55. A motor that stalls while starting or fails to start probably has a

1. worn bearing
2. grounded winding
3. faulty centrifugal switch
4. burned-out winding

5-56. Why does the accumulation of dirt, moisture, and oil in generator and motor ventilation ducts cause local or general overheating?

1. Resistance to the dissipation of heat is decreased
2. Resistance to the dissipation of heat is increased
3. Moisture and dirt form a nonconducting paste
4. Oil and dirt form a nonconducting paste

5-57. The accumulation of iron particles on motor or generator windings is particularly harmful, because the particles will puncture insulation as a consequence of being

1. removed with a dry rag
2. agitated by magnetic pulsations
3. disturbed by air circulating through the windings
4. absorbed by moisture or oil

5-58. Suction cleaning of motors and generators is preferred to other methods because it lessens the possibility of damage to the

1. insulation
2. commutator
3. brushes
4. soldered parts

5-59. When blowing dust from a 25-kw generator with compressed air, you must be sure to use which of the following?

1. Clean dry air
2. A suction blower at an opening opposite the air jet
3. Air pressure of less the 30 psi
4. All the above

5-60. What substance can be used in an emergency as a cleaning solvent for electrical equipment?

1. Water
2. Alcohol
3. Benzine
4. Carbon tetrachloride

5-61. What is the efficiency and toxicity of trichloroethylene as compared to type II dry cleaning solvent?

1. Toxicity is less and efficiency is greater
2. Efficiency is less and toxicity is the same
3. Toxicity is greater and efficiency is greater
4. Toxicity is less and efficiency is less

5-62. Which of the following safety precautions should you take when using a solvent for cleaning electrical equipment?

1. Have a fire extinguisher on the scene for immediate use
2. Use safety type portable lights if additional lighting is required
3. Remove vapors with exhaust fans or portable blowers
4. All of the above

5-63. By what means are shaft currents kept from flowing through the outboard bearing of a generator on which the bearing pedestal is insulated from the base and the bearing oil piping?

1. Insulating shims under the pedestal
2. Insulated holddown bolts and dowels
3. Insulated couplings in the bearing inlet and outlet oil piping flanges
4. All of the above

5-64. What technique should you use to clean oil and dirt from uncoated copper contact surfaces?

1. Varnishing
2. Sandpapering
3. Silver polishing
4. Moistening with an approved solvent

5-65. New motors or generators are delivered from the manufacturer with the grease cups removed from the bearing housing and replaced with pipe plugs. Where should the grease cups for the new motors or generators be?

1. With the responsible maintenance personnel
2. With the onboard repair parts or special tools
3. With the other grease cups in the workshop or toolroom

5-66. Where should grease cups for a motor be kept when they are not being used to grease bearings?

1. In the workshop or toolroom in the custody of responsible maintenance personnel
2. In a bag attached to the motor
3. On a wire attached to a pipe plug
4. On a wire attached to the motor

5-67. In the absence of other instructions, at what level should you maintain the oil in an oil-lubricated, ball bearing motor housing?

1. Approximately level with the top of the bearing
2. Almost level with the bearing inner ring at the lowest point
3. Level with the center of the bearing
4. Approximately level with the highest point of the bearing inner ring

5-68. To what extent should you run a motor while adding grease to the motor bearings?

1. Intermittently
2. Continuously
3. 3 minutes
4. 10 minutes

5-69. Bearings that require a silicone grease lubricant normally operate at a minimum temperature of

1. 82° C
2. 82° F
3. 90° C
4. 90° F

5-70. Why is it a rare practice to take air gap measurements on ball bearing machines?

1. Machine construction prevents bearing wear
2. Machine construction assures bearing alinement
3. Air gaps are too large to measure with a feeler gage
4. Air gaps are too small to measure with a feeler gage

5-71. Assume that you are taking air gap measurements on a six-pole d-c generator. Which of the following measurements should you take if one end (A) is accessible and the accessibility of the other end (B) is difficult?

1. At ends (A) and (B), 2 measurements spaced approximately 90°
2. At end (B), 6 measurements spaced approximately 60°; at end (A), 2 measurements 90° apart
3. At end (A), 4 measurements spaced approximately 90°; at end (B), 2 measurements 90° apart

5-72. Assume that you are filling the oil labyrinth of a ring-oiled sleeve bearing that is fitted to a 3/4-inch armature shaft. The bearing housing is not fitted with an overflow gage or an oil filter gage. You have filled the labyrinth to the proper height when the oil ring dips into the oil to a depth of approximately

1. 3/8 in.
2. 1/2 in.
3. 3/4 in.
4. 1 1/2 in.

5-73. Which of the following separates the bearing surface from the rotating journal?

1. An oil seal
2. The bearing housing
3. An oil film
4. An opening at the top of the bearing

5-74. At what maximum temperature can sleeve bearings and the outer races of ball bearings be allowed to operate?

1. 90° C for sliding contact bearings
2. 120° C for rolling contact bearings on class A insulated motors
3. 150° C for rolling contact bearings on class H insulated motors
4. 120° C for rolling contact bearings on class B insulated motors

5-75. In case an attachment plug has no cord-grip, you tie an Underwriter's knot in the cord to

1. adapt the plug to fit a 2- or 3-slot outlet receptacle
2. eliminate tension on the terminal connections in the plug
3. ground the connected equipment properly

Assignment 6

Shopwork (continued); Interior Wiring

Textbook NAVEDTRA 10636-H: Pages 223-269

Learning Objective: Point out principles of operation of the components in major electrical appliances.

- To answer items 6-1 and 6-2, refer to textbook figure 7-57.

6-1. The operating immersion control in the oil burner circuit of a forced hot-water heating system energizes which of the following components?

1. Circulator motor
2. Thermostat
3. Stack switch
4. Transformer

6-2. After the thermostat is satisfied, it turns off the relay which stops the

1. circulator motor only
2. burner motor only
3. circulator motor and burner motor

6-3. During the wash cycle of an automatic washer, the agitator is controlled by a

1. two-speed motor running on low speed
2. two-speed motor running on high speed
3. clutch
4. two-speed transmission operating in second gear

6-4. Temperature of the air that passes through the clothes in an electric dryer is controlled by the

1. timer
2. safety thermostat
3. high- and low-limit thermostats
4. electric heater

6-5. Refer to textbook figure 7-63. What is the position of the double-throw thermostat when the top part of the tank has reached its preset temperature?

1. Top contact open, bottom closed
2. Top contact closed, bottom open
3. Top contact open, bottom open
4. Top contact closed, bottom closed

6-6. The most reliable method of testing switches in an electric range is to measure their

1. resistance
2. voltage
3. current
4. temperature

6-7. Of the following, which causes the starting relay of a hermetic compressor to close its contacts on start?

1. High starting current
2. High running current
3. Out-of-phase, magnetic field
4. Motor speed increase

6-8. The electric timer clock of textbook figure 7-73 is preset to defrost the refrigerator by energizing the heaters in the freezer section.

Learning Objective: Using a trouble-shooting chart, identify the causes of troubles in window air-conditioners.

In answering items 6-9 through 6-12, select from column B the trouble which is caused by the fault in column A. (Refer to textbook figure 7-71.)

	A. Faults		B. Troubles
6-9.	Defective unit starting switch	1.	Unit blows fuses
6-10.	Faulty running capacitor	2.	Unit will not run
6-11.	Incorrect fuse	3.	Fan runs, compressor will not operate
6-12.	Inoperative thermostat		

Learning Objective: Indicate principles and techniques of installing an interior wiring system.

6-13. All interior wiring systems that CE's install or maintain must conform to the specifications issued by NAVFAC.

6-14. The type and size of wiring most frequently used for interior jobs is

1. solid No. 14 AWG
2. stranded No. 12 AWG
3. stranded No. 14 AWG
4. solid No. 12 AWG

6-15. If ten No. 12 AWG conductors are placed in the same conduit, their current-carrying capacity equals

1. 12 amp
2. 14 amp
3. 16 amp
4. 20 amp

6-16. In running a length of 7/8-inch-diameter Romex cable in a quonset building, it is necessary to make some 90° bends. What is the minimum radius of bend for this cable?

1. 1.3 in.
2. 4.5 in.
3. 6.0 in.
4. 7.5 in.

6-17. A wiring plan calls for installing a cable by direct burial in a location where the cable will be exposed to both wet and dry conditions and temperatures in excess of 100°F. The rubber insulation used should be that specified by the NEC as type

1. R
2. RHW
3. RH
4. RU

In items 6-18 through 6-20, select from column B the location in which the type of wire insulation in column A is used.

	A. Types of Insulation		B. Locations
6-18.	TA	1.	Switchboard
6-19.	TW	2.	Underground installation
6-20.	Asbestos	3.	Transformer lead in dry area
		4.	Dry: above 200°F, 220-volt system

6-21. A conduit threading die is used to

1. thread only conduit over 1 inch in diameter
2. make a tapered thread on conduit
3. thread and cut conduit in one operation

● To answer items 6-22 and 6-23, assume you are making a 90-degree bend in a length of 1/2-inch conduit at a distance of 36 inches from one end.

6-22. To make the first bend of about 25 degrees, you place the conduit hickey so that its back edge is how far from the end of the conduit?

1. 28 in.
2. 30 in.
3. 32 in.
4. 34 in.

6-23. For the second bend you place the back edge of the hickey 36 inches from the end of the conduit and bring the bend up to

1. 30°
2. 45°
3. 70°
4. 90°

6-24. A CE finds that a run of conduit between pull boxes will have five 90° bends. What, if anything, should he do to complete the conduit run?

1. Use a concealed condulet
2. Increase the radius of each bend
3. Use a condulet instead of one of the bends
4. Nothing

6-25. The type of fastener required to secure a length of conduit to a wall depends primarily on the

1. length of the conduit section
2. number of conductors connected in the circuit
3. composition of the wall
4. composition of the conduit

6-26. The type of connector most generally used for linking thin-wall waterproof conduit length to length is the

1. threaded
2. indenter
3. compression
4. setscrew

6-27. Compared with the threadless method of joining metallic conduit, the method of joining PVC conduit is superior because the finished joints are

1. waterproof and vaporproof
2. explosionproof
3. corrosion resistant

6-28. What is the minimum radius that you should use when making a right-angle bend in a length of 1/2-inch PVC rigid conduit?

1. 1 in.
2. 5 in.
3. 3 in.
4. 7 in.

6-29. If you must connect the motor of a sump pump in a basement area to a source of electric current, which type of conduit is most suitable for the wiring?

1. Standard metal
2. Romex
3. Latex liquid-tight
4. BX

In items 6-30 through 6-34, select from column B the use for the outlet box in column A.

	A. Types of Outlet Boxes	B. Uses
6-30.	Gem box	1. Ceiling outlet
6-31.	Handy box	
6-32.	Octagon box	2. Exposed wiring
6-33.	4-11/16 inch square box	3. Switches
6-34.	4- inch square box	4. Range receptacles

In items 6-35 through 6-37, select from column B the distance from the floor that is required in the installation of the type of receptacle in column A.

	A. Types of Receptacles	B. Distances Above Floor
6-35.	Wall fan	1. 46 in.
6-36.	Toggle switch	2. 48 in.
6-37.	Abovecounter	3. 78 in.
		4. 84 in.

6-38. A 230-volt air conditioner should be served by a receptacle provided with one ground contact and

1. three horizontal slots
2. two horizontal slots
3. three slanted slots
4. two slanted slots

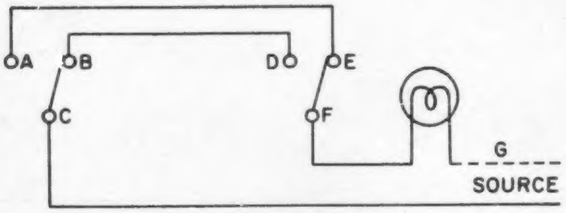


Figure 6A

6-39. The broken line G in figure 6A represents the

1. hot wire
2. neutral wire
3. traveler
4. toggle

6-40. The lamp in the circuit of figure 6A will not light up when the switch blades are in the positions represented by

1. AC and EF
2. BC and DF
3. BC and EF

6-41. Sketch a single light connected to a power source through two 3-way switches. Your sketch should show all but which of the following conditions?

1. The neutral wire connected directly to one side of the light
2. The hot wire connected directly to one switch
3. Two travelers connected between switches
4. The light connected between the center poles of both switches

6-42. The most hazardous space inside the building of a gasoline station is located

1. within 18 inches of the floor
2. within 18 inches of the ceiling
3. between the spaces described in 1 and 2 above

6-43. Except in specially approved cases, the minimum wire size that may be used for a service entrance conductor is

1. No. 6
2. No. 10
3. No. 12
4. No. 14

6-44. When installing a service entrance conduit, you must be sure to

1. enclose all spliced, aboveground, service entrance conduit
2. use No. 8 AWG wire
3. run conductors, without splices, from the weatherhead to the connections in the entrance service switch
4. use conduit whose diameter is at least 1.5 inches

6-45. When an underground service conduit enters a building through a concrete floor, it is fitted with a

1. condulet at the point where the conduit is brought through the floor
2. coupling whose top is made flush with the finished floor
3. thermoplastic insulator
4. rubber insulator

6-46. What minimum size of entrance switches must be used for fuse type and circuit breaker type service, respectively?

1. 30 amp; 50 amp
2. 50 amp; 30 amp
3. 50 amp; 60 amp
4. 60 amp; 50 amp

6-47. What type of automatic circuit breaker is normally used for (A) lighting panels and (B) power panels?

1. 15-amp single-pole for A, and 2-pole for B
2. 15-amp single-pole for A and 1-, 2-, or 3-pole for B
3. 15-amp double-pole for A and single-pole for B
4. 15-amp double-pole for A and 1-, 2-, or 3-pole for B

6-48. A distribution panel feeds two identical electrical loads, A and B. The best location for this panel is

1. at load A only
2. at either load A or at load B
3. between the two loads
4. near the entrance switch

6-49. Besides being listed numerically from top to bottom, how should the circuits on the panelboard be listed for clear identification?

1. Even numbers on the left
2. Odd numbers on the left
3. Odd numbers on the right

6-50. A 3-wire distribution system has two hot wires and a neutral wire. How much current will the neutral wire carry when one hot wire carries 3 amperes and the other hot wire carries 1 ampere?

1. 1 amp
2. 2 amp
3. 3 amp
4. 4 amp

6-51. Which of the following wire combinations is typical of 4-wire electrical systems?

1. 1 hot wire and 3 neutral wires
2. 2 hot wires and 2 neutral wires
3. 3 hot wires and 1 neutral wire
4. 4 hot wires and no neutral wire

6-52. The neutral wire in a conductor may be identified by its

1. green insulation
2. white or gray insulation
3. black or red insulation
4. lack of any insulation

6-53. When wires are being pulled through a conduit, which of the following practices is NOT recommended as a means of facilitating the work?

1. Baring insulation from the wire ends
2. Applying talc to the wire insulation
3. Coating the wire insulation with grease
4. Taping the wires to the hook of a fish tape

6-54. Your wiring plan requires that exposed cable run horizontally to the floor joists above a basement floor. The cable should be run

1. through bored holes in the floor joists or on a running board
2. across the edges of the joists and secured with straps
3. through rigid steel conduit strapped to the joists
4. through type I plastic conduit strapped to the joists

6-55. The purpose of the overcurrent device in a motor branch circuit is to protect the motor, wires, and controls.

6-56. A fuse or circuit breaker is an adequate means of disconnecting a stationary motor provided its horsepower rating is

1. 1/8 hp or less
2. 1/4 to 5/8 hp
3. 3/4 to 1 hp

6-57. What type of splice, if any, may be pulled through a conduit?

1. Duplex
2. Western Union
3. Wrapped
4. None

6-58. When soldering two conductors that are too large to be heated adequately with a soldering iron, what means should you use to heat them?

1. An electric oven
2. Molten solder
3. An alcohol torch
4. An oxyacetylene torch

6-59. The timelag fuse protects against a short circuit better than an ordinary plug fuse does.

6-60. Which of the following conditions will cause a cartridge fuse to overheat or blow at less than its rated current?

1. Overly tight clip clamp
2. Poor clip contact
3. Old fuse link

6-61. You can cause a burr on the ferrule or terminal of a cartridge type fuse by

1. inserting the fuse on a live circuit
2. brightening the fuse with emery cloth
3. tightening the spring clip

6-62. Which of the following conditions causes a fuse link to blow at a point between the reduced portion and the end of the link?

1. Short circuit
2. Poor contact
3. Light overload

6-63. When part of a circuit is out and the fuses have NOT blown, which of the following conditions exist?

1. Grounded circuit
2. Shorted circuit
3. Open circuit
4. Overloaded circuit

6-64. You are using a 200-watt lamp to determine the cause of trouble in a building wiring circuit. Which of the following conditions is an indication of a short?

1. The lamp burns at full brilliancy with the neutral open
2. The lamp burns with the neutral closed but goes out when the neutral is opened
3. The lamp does not light with the neutral open or closed

Learning Objective: Identify characteristics of incandescent lamps.

In items 6-65 through 6-67, select from column B the type of lamp having the design characteristic in column A.

A. Design Characteristics

6-65. Made of special glass whose resistance to thermal shock is high

6-66. Last twice as long as regular general service incandescent lamps

6-67. Installed where lamp replacement costs are high

B. Types of Lamps

1. Clear Lamps
2. Quartz iodine lamps
3. Hand-glass lamps
4. Long-life lamps

Learning Objective: Recognize operating principles of fluorescent and incandescent lighting systems and techniques of maintaining them.

6-68. Why is a ballast required in a fluorescent lamp?

1. To limit current and supply proper voltage
2. To limit voltage and supply proper current
3. To act as a capacitor to improve power factor
4. To act as a reactor to improve power factor

Refer to table 6-2 in your textbook in answering items 6-69 through 6-71.

6-69. What condition could cause incandescent lamps in a lighting circuit to burn out frequently?

1. High voltage
2. Excessive vibration
3. Use of lamps having wrong rating
4. Each of the above

6-70. A fluorescent lamp is slow to light after the switch is turned on. If the line voltage is proper, what should you do to correct the condition?

1. Turn the luminaire on and off several times
2. Replace the starter
3. Remove the lamp and scrape the ends
4. Seat the lamp firmly

6-71. Which of the following is the best indication that a fluorescent lamp is nearing the end of its useful life and will soon burn out?

1. Slow starting
2. Increased noise from the ballast
3. Flickering
4. Flashing on and off

6-72. A smaller percentage of light is reclaimed by washing light reflecting surfaces than by dry wiping them.

6-73. A burned out fluorescent lamp in a live circuit may cause damage to the

1. line switch
2. ballast
3. electrodes
4. lamp holder

Assignment 7

Central Power Stations

Textbook NAVEDTRA 10636-H: Pages 270-304

Learning Objective: Indicate characteristics of generators and generator accessories and principles of generating electricity.

7-1. Refer to textbook table 9-1. Which of the following gasoline-driven, alternating-current generators allows for a 120-volt, single-phase, 2-wire panel connection?

1. 5 kw
2. 30 kw
3. 45 kw
4. 75 kw

7-2. The initial cost of a gasoline engine generator is lower than that of a diesel engine generator, but the maintenance costs are higher.

7-3. Which of the following generating requirements for communications and lighting can be met with the 1.5-kw gasoline-driven generator?

1. 120 volts, single-phase, 60 hertz
2. 120/208 volts, 3-phase, 50 to 60 hertz
3. 120/240 volts, 3-phase, 50 to 60 hertz
4. 120 volts, 3-phase, 60 hertz

7-4. Which of the following are important factors in the selection of advanced base generating equipment?

1. Voltage, phase, and frequency of power output
2. Load deviation and availability of fuel
3. Life of the installation and availability of skilled personnel
4. All of the above

7-5. Acceptable values of an active advanced base's (a) annual load factor and (b) power factor would be

1. (a) 40%; (b) 95%
2. (a) 45%; (b) 90%
3. (a) 55%; (b) 80%
4. (a) 60%; (b) 75%

7-6. The control panel for a central power plant consisting of two main generators is referred to as

1. a switchyard
2. switchgear
3. a switchboard
4. a control board

7-7. The governor on an engine-driven alternator is used to maintain constant

1. output voltage by automatically adjusting engine speed
2. output voltage by automatically adjusting resistance
3. output frequency by automatically adjusting resistance
4. output frequency under different load conditions

7-8. Before shutting down the prime mover of a power generating system, what action must you take to prevent dangerously high voltage from building up when the field circuit is suddenly opened?

1. Adjust the field rheostat so that resistance will be decreased
2. Push the starter switch to the OPEN position
3. Throw the field switch to the OFF position
4. Connect the exciter field so that no shunting will occur across the exciter field coils

7-9. The function of the field rheostat in an alternator unit is to

1. dissipate sharp increases of voltage in the exciter
2. control the voltage output of the exciter
3. disconnect the exciter armature from the exciter field
4. set the value at which the voltage regulator holds the voltage constant

7-10. To obtain readings of the voltage and current output of a 3-phase generator, you should use the

1. voltage-regulator switch
2. voltage-regulator rheostat
3. field rheostat
4. meter switch

7-11. The power generated at the central power station is distributed from load point terminals called

1. switchgear
2. output cables
3. load terminals
4. bus bars

7-12. Which of the following switchboard instruments eliminates the need for numerous readings to determine power output?

1. Voltmeter
2. Ammeter
3. Wattmeter
4. Watt-hour meter

Learning Objective: Describe operating principles of statically regulated controlled rectifier (SRCR) generators.

7-13. Refer to figure 9-8 of your textbook and give the direction of current flow from the two power rectifiers.

1. To stator, then revolving field, then heat sink
2. To heat sink, then revolving field, then stator
3. To stator, then heat sink, then revolving field
4. To heat sink, then stator, then revolving field

7-14. Which component in the circuit of textbook figure 9-9 controls the field current of an SRCR generator?

1. Field rectifier
2. Silicon control rectifier
3. Power rectifier
4. Main heat sink

7-15. Under what load condition does the silicon controlled rectifier (SCR) allow little current to reach the field?

1. Full load
2. No load
3. Half load

7-16. What component of an SRCR generator can be damaged during its operation if metal contact is made between the generator frame and heat sink?

1. Stator
2. Field rectifier
3. Controlled rectifier
4. Blocking diode

7-17. Which of the following components in the voltage control circuit of textbook figure 9-12 protects the controlled rectifier in the event the rectifier shorts?

1. Blocking diode
2. Buildup relay
3. Buildup resistor
4. Regulator assembly

7-18. The regulator assembly of textbook figure 9-13 contains a circuit whose function is to

1. turn the SCR off
2. trigger the SCR
3. control the voltage added to the regulator
4. reduce voltage pulses across the SCR

In items 7-19 through 7-22, select from column B the part of the voltage level sensing circuit that carries out the function.

	A. Functions	B. Parts
7-19.	Holds the generator voltage constant as engine speed droops	1. Filter choke
7-20.	Makes the regulator circuit independent of generator frequency	2. Sensing reactor
7-21.	Smooths out the voltage sent from the voltage sensing circuit to the triggering circuit	3. Noise Suppression
7-22.	Eliminates radio static produced by the generator	4. Regulator

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7-23. The primary winding of instrument transformer A is wound around a line carrying 200 amperes. The primary winding of instrument transformer B is wound around a line carrying 100 amperes. If instrument transformer A has a secondary winding with a current rating of 5 amperes, instrument transformer B will probably have a secondary winding with a current rating of

1. 2 1/2 amp
2. 5 amp
3. 10 amp
4. 25 amp

7-24. A transformer's low side is usually wound for 110 volts. What determines the ratio of turns on one side to turns on the other side?

1. Rating of the low-voltage side
2. Rating of the high-voltage side
3. Difference in the ratings of the low-voltage and high-voltage sides

Before alternators are paralleled, they must be operating at nearly the same speed, with the incoming one running slightly faster, since it will slow a bit as it takes the load. At the instant the new generator is switched on the line, it should be exactly in phase with the other.

7-25. The pointer of a synchroscope, textbook figure 9-14, must be in what position when an alternator is placed on the line parallel to another alternator?

1. Rotating slowly in the slow direction and at 12 o'clock
2. Rotating slowly in the fast direction and at 12 o'clock
3. Rotating fast in the fast direction and at 6 o'clock
4. Stationary at 6 o'clock

7-26. The work performed in an a-c generator by its slip rings, and commutator is done essentially by the action of

1. a bridge rectifier
2. a rheostat
3. the exciter field stator
4. the generator armature stator

Learning Objective: Indicate fundamentals in the selection and installation of generating equipment.

7-27. A generator supplying power for an advanced base should be located near the

1. barracks site
2. edge of the base
3. points of small demands
4. points of large demands

7-28. If you have to supply 4,200 watts of power to a 120-volt, single-phase load, excluding motors, what size and type of generator will you need?

1. 3-kw, 2-wire
2. 3-kw, 3-wire
3. 5-kw, 2-wire
4. 5-kw, 4-wire

7-29. How should you compute the demand factor of a system? Assume that all pertinent values are given for, or obtained during, the system's period of greatest demand.

1. Multiply the system's true power by the current flowing through the load and divide by the voltage impressed on the load
2. Measure the actual power used and divide by the power requirements of all the system's equipment
3. Add the rated capacities of all electrical appliances, lights, heaters, motors, etc for each feeder; divide the smallest sum obtained by the largest sum obtained
4. Measure the actual current through the load on each feeder; divide the smallest current value by the largest current value

7-30. The total connected load for your repair shop is 60 kw while the maximum demand is 40 kw. What is the demand factor?

1. 26%
2. 50%
3. 66%
4. 75%

7-31. How do you determine the power factor of an electrical load?

1. Measure the actual current through the load on each feeder; divide the smallest current value by the largest current value
2. Measure the actual power used and divide by the power requirements of all the system's equipment
3. Add the rated capacities of all electrical appliances, lights, heaters, motors, etc for each feeder; divide the smallest sum obtained by the largest sum obtained
4. Divide the load's wattmeter reading by the product of the load's voltage and current flow

7-32. What is the true power of a 120-volt single-phase motor that is drawing 15 amperes and has a rated power factor of 80 percent?

1. 1272 watts
2. 1440 watts
3. 2491 watts
4. 3114 watts

7-33. Suppose two generators, A and B, are producing the same amount of power. Generator A operates with 50 percent power factor, generator B with a 100 percent power factor. Compare the amounts of current they require.

1. A requires twice as much as B
2. A requires four times as much as B
3. A requires one-half as much as B
4. A requires the same amount as B

7-34. When wired to an electrical system, which of the following devices do NOT affect the reactive power of the system?

1. Drive motors
2. Electric motors
3. Constant-current regulators
4. Welders

7-35. Assume you have the responsibility of providing shelter for advanced base generators. Before the Builders can construct a shelter, you must furnish them all the following information, EXCEPT the

1. number of generators to be sheltered
2. size of the generators
3. electrical power load
4. arrangement of the exhaust system

7-36. Excess engine heat produced by a large generator set operating in a building can be removed by

1. providing suitable exits for exhaust gases
2. opening all doors and hatches on the generating set
3. placing the generator set on mounting shocks
4. providing large louvered openings in the building walls at the front and back of the generator set

7-37. What is the best way of getting rid of carbon monoxide gas produced by a diesel-driven generator?

1. Extend the engine's exhaust pipe to the outside of the building
2. Cool the gas in a cold water bath prior to exhaust
3. Make certain that there are open fresh air ducts in the roof of the generator building
4. Open all the doors and hatches on the generator set before starting it

7-38. Which of the following parts of an electrical power distribution system do NOT need to be grounded?

1. Transformer tanks
2. Generator bases
3. Distribution buses
4. Neutral wires

7-39. Refer to the representative grounding plan for an advanced base plant in textbook figure 9-21. What type of grounding cable is used at points R and A?

1. Mild plow steel
2. Insulated copper
3. No. 6 bare copper
4. 1/0 bare stranded cable

7-40. Assume you are connecting a branch ground cable to the main ground cable, using ground clamps. What must you do to the cable before tightening the ground clamps?

1. Take ground meter readings
2. Jumper all connections
3. Thoroughly clean the metal
4. Wash the metal with saltwater

7-41. Which of the following advantages does the thermit type of welding process provide for connecting branch cables to main cables?

1. It is less costly than other welding methods
2. It uses lower temperatures than brazing or soldering
3. The weld is usually completed within 10 seconds with no damage to conductor insulation
4. Each of the above

● When answering items 7-42 through 7-44, refer to textbook table 9-2.

7-42. When it is necessary to obtain a 127/220, 3-phase, 4-wire voltage from a 3-phase generator you should connect the line leads to

1. T2 and T9; T8; T3 and connect T5 to T6
2. T3, T8 and connect T2 and T9 and T5 to T6
3. T2, T1, T3 and connect T4 to T7, T6 to T9 and T5 to T8
4. T1 and T7, T3 and T9, T2 and T8 and connect T4, T5, T6 and TO

7-43. Which of the following coil lead combinations do you use to obtain 220-volt, single-phase power from a 3-phase, dual-voltage generator?

1. T1 and T2; T3 and T8
2. T2 and T8; T3 and T9
3. T1 and T4; T7 and TO
4. T3 and T4; T8 and T9

7-44. Which coil leads should be properly insulated when NOT used for single-phase service?

1. TO, T1, T4, and T2
2. TO, T1, T4, and T7
3. T7, T4, T1, and T3
4. T1, T4, T7, and T2

7-45. Which of the following is a consequence or result of generator leads to meet certain load conditions?

1. Change in the size of fuse needed to protect the generator
2. False reading of the switchboard ammeter
3. Change in the generator voltage output and rated current
4. Each of the above

7-46. Assume that the output voltage of a generator not equipped with a changeover block is to be reconnected from 220-volt to 440-volt operation. The meter shows a full-scale deflection at the full load current of 76 amp. If you reconnect to 220 volts without changing the current transformer connections from mid-tap to full position, a full load current will produce a meter deflection of

1. 1/4 scale
2. 1/2 scale
3. 3/4 scale
4. full-scale

7-47. Tap connections on the voltage regulator must be changed in order to keep constant the ratio of primary voltage to secondary voltage.

7-48. A changeover block on an advanced base generator is used as a means of

1. disconnecting the generator leads from the potential transformers
2. disconnecting the generator leads from the current transformers
3. rearranging the connections of load cables to change phase rotation
4. rearranging internal windings of the alternator by coil lead reconnections

7-49. A bus bar may be used as the central point for collecting the paralleled outputs of two or more generators of a portable generating station.

7-50. Assume you must change a feeder line running to Company A shop area. Which of the following steps must be taken before any work is to be done on the line and generator?

1. Shut off the generator prime mover
2. Close the switch leading to feeder line
3. Lock the internal circuit breaker in OFF position
4. Both 2 and 3 above

7-51. Which of the following factors is important in the installation of a bus bar system?

1. Determining the size of wire that will carry the load current
2. Using circuit breakers or fuse knife switches to control the output of each feeder line
3. Supplying generators properly
4. Each of the above

7-52. Placing capacitors as close to the inductive load as possible provides

1. maximum power factor correction from the capacitor back to the source of power
2. minimum power factor correction from the capacitor back to the source of power
3. protection in the event of an open circuit
4. power factor improvement in series circuits

Learning Objective: Indicate techniques of inspecting and servicing a generator set.

7-53. What step in the process of placing a generator in operation follows your visual inspection of the generator?

1. Servicing the generator
2. Servicing the prime mover
3. Setting up the generator
4. Setting up the generator shelters

7-54. Assume that you must prepare your own electrolyte for the battery used to start your advanced base electric power generator. You are using an acid of 1.835 specific gravity and desire a specific gravity of 1.290. What proportions of water and acid do you use?

1. 11 parts water; 4 parts acid
2. 8 parts water; 3 parts acid
3. 5 parts water; 2 parts acid
4. 2 parts water; 1 part acid

7-55. You check the temperature of the electrolyte being added to a storage battery and find that it is within the proper range. Which of the following is a possible temperature of the electrolyte?

1. 40°F
2. 55°F
3. 75°F
4. 100°F

7-56. What is the minimum amount of time that you should let a battery freshly filled with electrolyte stand before you put it in service?

1. 5 min
2. 20 min
3. 1 hr
4. 24 hr

7-57. As a general rule for charging batteries, the rate of charge is low. The duration of charge, however, is measured from the time it takes battery voltage and specific gravity (corrected to 80°F) to become constant. Give the approximate charging rate and the measured time of charge.

1. One ampere, one hour
2. Three amperes, three hours
3. Five amperes, five hours
4. Seven amperes, seven hours

7-58. You can shorten the warmup period for the 600-kw generator by

1. opening and latching the fan cover
2. covering the main diesel engine exhaust stacks
3. closing the bypass shutters or doors
4. closing the roof hatches and side louvers

7-59. Suppose you are to calculate for generator collector brush pressure. Use the following: Manufacturer's recommended tension, 60 ounces; brush width, 5/8 inch; brush thickness, 1 1/2 inches. What is brush pressure per square inch?

1. 4.0 psi
2. 3.288 psi
3. 3.459 psi
4. 2.988 psi

7-60. In wintertime, you can minimize the amount of moisture that condenses in the fuel tank of a gasoline engine by refilling the tank after every watch or oftener.

7-61. After tightening connections, how should you treat battery terminals to reduce corrosion?

1. Clean them with solvent
2. Coat them lightly with grease
3. Wipe them off with a dry rag
4. Wipe them off with steel wool

Learning Objective: Indicate principles and techniques of operating a power station.

7-62. Which of the following purposes is served by the engine operating lever of a diesel-driven a-c generator?

1. Regulation of engine speed during normal operation
2. Admission of compressed air for starting the engine
3. Exact matching of engine speed to the frequency of an energized bus
4. Manual control of engine speed during starting and stopping

7-63. The governor of a diesel-driven generator holds the engine to an operating speed selected by the operator. To make minor adjustments in this regulated speed, you must use the

1. speed control lever
2. operating lever
3. vernier knob
4. pawl-actuating lever

7-64. Assume the engine speed is controlled by the governor. To transfer the engine from governor speed control to engine stop, which lever must you operate?

1. Engine operating lever
2. Pawl-actuating lever
3. Latch lever
4. Each of the above

7-65. Once the output of an a-c generator is properly matched to the bus requirements, you should energize the bus by operating the

1. generator circuit breaker
2. voltage regulator switch
3. field switch
4. motor governor control switch

7-66. Before two or more a-c generators may be operated in parallel to feed a single bus, their output must be carefully matched in all characteristics EXCEPT

1. voltage
2. current
3. frequency
4. phase

7-67. Assume you must parallel another generator on the line. Normally, you synchronize them by using the lamp method or a synchroscope. When using the lamp method, how many lamps should glow and how many should remain dark the instant the two generators are parallel?

1. One bright, two dark
2. Two bright, one dark
3. Two bright, two dark
4. One bright, one dark

7-68. Suppose the "all-dark" method is used to synchronize and it is not possible to obtain lamps having a voltage rating twice the generator terminal voltage. What other devices can be used instead of these lamps?

1. Stepdown transformers
2. Several lamps in series
3. Voltage dropping resistors
4. Any of the above

7-69. The method of synchronizing large, high-speed generators requires that the line circuit be closed when

1. all lamps reach minimum brightness
2. all lamps are of equal brilliancy
3. the incoming alternator's frequency is slightly behind the already-operating alternator's frequency
4. the incoming alternator's frequency is slightly greater than the already-operating alternator's frequency

7-70. You are paralleling a new generator onto the line. You will connect the generator into the circuit when the indicator of the synchroscope shown in figure 9A is

1. steady over the vertical indicator
2. just to the left of, and slowly approaching, the vertical indicator
3. just to the right of, and slowly approaching, the vertical indicator
4. turning slowly in either direction, and directly over the vertical indicator

7-71. To control the load on paralleled generators, you will normally adjust the

1. generator speed
2. field current regulator
3. series field rheostat
4. shunt field rheostat

7-72. After you have cut in an alternator on an energized line, you must adjust the voltage regulator to obtain the desired

1. power factor
2. load balance and line frequency
3. line frequency
4. phase relationship

7-73. Which of the following steps should you perform first when you must secure a generator from parallel operation?

1. Open the field switch
2. Shift the load to the other generators
3. Stop the engine
4. Trip the generator circuit breaker

7-74. Which of the following events ought to take place in case of an overspeeding engine, and overheated engine, or low lubricating oil pressure?

1. The main circuit breaker trips
2. The engine shuts down
3. A light or alarm indicates the malfunction
4. Each of the above

7-75. Switchboard instruments show how the system is operating and reveal overloads, improper division of kilowatt load, and other abnormal operating conditions.

Assignment 8

Central Power Stations; Overhead Power Distribution

Textbook NAVEDTRA 10636-H: Pages 304-349

Learning Objective: Indicate principles of standing watch at a power station and identify operator maintenance practices.

8-1. How many watches are scheduled for each 24-hour period at most Navy central power stations?

1. Three
2. Four
3. Six
4. Eight

8-2. One purpose of keeping a generator station log is to help determine when a particular piece of equipment needs preventive maintenance.

8-3. To be used for log entries, a form must not only describe the hourly performance of the generators, but also the performance of all controlling and indicating devices of the equipment.

8-4. All of the following are daily maintenance practices EXCEPT

1. checking the fuel tank for leaks
2. checking the level of the coolant
3. draining water from the fuel tank
4. greasing the fuel transfer pump

8-5. When changing oil in the engine crankcase you should also change the

1. battery electrolyte
2. brushes
3. coolant
4. oil in the oil bath air cleaner

8-6. How often should the load contactor faces be cleaned?

1. Daily
2. Weekly
3. Every 3 months
4. Yearly

8-7. All but one of the following are operator maintenance practices to be performed every three months of generator operation. The exception is

1. inspecting the pole shader
2. renewing the oil filter element
3. cleaning load contactor faces
4. greasing the fuel transfer pump

8-8. Inspections of generator plant switchgear equipment should be made at least once every

1. week
2. month
3. 6 months
4. year

8-9. Which of the following steps is normally included in a yearly check of switchgear components?

1. Checking for burned out indicating lamps
2. Testing the operation of the switchgear position-changing mechanisms
3. Wiping all dust from the bus bars and insulating material
4. Each of the above

8-10. When the main contactor switch opens and shuts down the engine, and the oil pressure indicator bulb light up, the generator's engine oil pressure has fallen below 10 psi.

8-11. Personnel engaged in working on an energized circuit must be insulated from ground and have adequate lighting.

Learning Objective: Identify fundamentals of troubleshooting SRCR controlled regulators.

8-12. Which of the following will cause a power rectifier to fail?

1. Excessive current
2. Excessive voltage
3. Lack of silicon lubricant
4. Each of the above

8-13. The resistance of a power rectifier is greater when the direction of current flow is from plus to minus than when the direction is minus to plus.

8-14. When does a silicon controlled rectifier allow direct current to flow?

1. Only when a large positive voltage is applied to its gate terminal
2. Only when a small positive voltage is applied to its gate terminal
3. Only when a small negative voltage is applied to its gate terminal
4. Only when a large negative voltage is applied to its gate terminal

8-15. Refer to textbook figure 9-40. At which terminals of a silicon controlled rectifier should you receive an ohmmeter reading of 10 to 250 ohms?

1. Anode and Cathode
2. Cathode and Gate
3. Cathode and Pigtail
4. Anode and Gate

8-16. Which type of rectifiers in generating station equipment allows all the alternating current to flow?

1. Single diode
2. Power SCR
3. Full-wave

8-17. You are troubleshooting a full-wave rectifier and have the ohmmeter hooked up to the No. 3 plus terminal and No. 4 minus terminal of the rectifier. What kind of ohmmeter reading indicates a faulty rectifier?

1. High
2. Low
3. None

8-18. In troubleshooting the component parts of the SRCR controlled regulator, for which of the following do you check the saturable reactor?

1. Resistance
2. Continuity and grounds
3. Excessive voltage
4. Excessive current

8-19. When placed in a circuit, what component of the SRCR controlled regulator is used to smooth out rough direct current?

1. Saturable reactor
2. Power rectifier
3. Choke
4. Any of the above

Identify fundamentals of designing an overhead power distribution system.

8-20. Which of the following are basic factors to consider in designing a powerline?

1. Transformer sizes, class of poles, and route
2. Pole heights and the number of men needed to pike poles
3. Transformer sizes, load requirements, and number of crossarms needed
4. Pole heights and direction that poles face on long runs

8-21. The 1-to-10 classification of wooden poles indicates the capability of a pole to resist an applied load at what point or points on the pole?

1. Midpoint between top and bottom of the pole
2. 2 feet from the top of the pole
3. 6 feet from the bottom of the pole
4. 10, 15 and 20 feet from the top of the pole

8-22. Which of the following types of insulators is designed for use with a 36,000- volt distribution system?

1. One-piece porcelain pin
2. Two-piece porcelain pin
3. Suspension
4. Each of the above

8-23. A primary voltage distribution feeder can be made to have a no-voltage condition and can be held in that condition while repairs are being made on the secondary line, if the feeders are equipped with

1. a secondary protective device
2. an oil circuit breaker
3. lightning arresters
4. disconnect switches

8-24. Which of the following circuit arrangements is provided by a lightning arrester?

1. Short circuit for high voltages and open circuit for line voltages
2. Short circuit for line voltages and open circuit for high voltages
3. Short circuit for direct current and open circuit for alternating current
4. Short circuit for alternating current and open circuit for direct current

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Learning Objective: Describe procedures and equipment for raising and guying poles.

8-25. The minimum distance between gains for crossarms where the voltage of the circuit will NOT exceed 3,700 volts must be at LEAST

1. 12 in.
2. 18 in.
3. 24 in.
4. 48 in.

8-26. Why should a pole hole be 6 inches larger on all sides than the pole, and why must the hole be larger at the bottom than at the top?

1. To allow for wood expansion due to water absorption and to prevent undue strain on the pole
2. To allow for tamping and for shifting the pole to an upright position
3. To allow cement to be added and to permit forming a cement cave
4. To provide water drainage and to allow shifting the pole after it has been placed

8-27. As each new position is reached in the process of raising a pole, the weight of the pole is temporarily supported by a

1. butt head
2. jenny
3. cant hook
4. crossarm

8-28. How is the term "facing the gains" related to the job of setting power poles?

1. On straight line runs the poles must be turned in their holes so the gains face each other in every other span
2. On curved runs the poles must be turned in their holes so the gains face each other in every other span
3. On straight line runs the poles must be turned in their holes so that the gains all face in one direction
4. On curved runs the poles are set in any position as long as the gains make the crossarm lie at right angles to the wire run

8-29. In helping to set powerline poles, a piker should not brace his pike pole on his stomach.

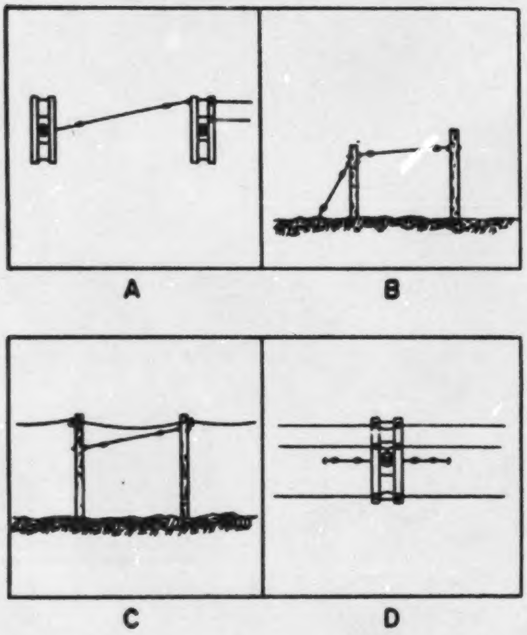

Figure 8A

8-30. Which parts of figure 8A illustrate, an application of a line guy, a head guy, an arm guy, and a stub guy, in that order?

1. A, C, B, D
2. B, D, A, C
3. C, D, A, B
4. D, C, A, B

8-31. Guying a pole is done in order to

1. maintain proper leveling of crossarms
2. keep the pole in position and help strengthen it
3. properly sag the individual wire spans
4. keep a pole-mounted transformer from pulling a pole out of alinement

8-32. The purpose of the porcelain strain insulators that are inserted in a guy is to

1. protect the guy from excessive strain
2. break up the guy into short lengths of electrically insulated segments
3. make the guy easier to install
4. allow for expansion and contraction of the guy with temperature changes

8-33. Which type of guy anchor is recommended for use in sand?

1. Never creep
2. Expanding
3. Log
4. Screw

Learning Objective: Identify fundamentals of inspecting and maintaining climbing equipment.

8-34. Upon discovering enlarged tongue holes on your safety belt, you should replace the safety belt.

8-35. The first step in the periodic servicing of the leather in your climbing equipment is to

1. rub down with a soft cloth
2. apply "neat's-foot oil"
3. apply saddle soap
4. clean with a damp sponge and mild soap

8-36. The maximum allowable difference in gaff length of a pair of climbers is

1. 1/16 inch
2. 1/8 inch
3. 1/4 inch
4. 3/8 inch

8-37. The proper length of the gaff on lineman's climbers is at LEAST

1. 1 1/4 inch on the inner face
2. 1 1/2 inch on the outer face
3. 1 1/2 inch on the inner face
4. 2 1/4 inch on the outer face

8-38. How should the gaffs be sharpened?

1. With a file, but not to a needlepoint
2. With a file, to a needlepoint
3. With an emery wheel, but not to a needlepoint
4. With an emery wheel, to a needlepoint

Learning Objective: Recognize techniques or practices in pole climbing and pole-top resuscitation.

8-39. While climbing a pole with the aid of climbers, why must you grasp each side of the pole with your hands?

1. To support a part of your weight
2. To provide proper balance
3. To aid in sinking the gaffs into the pole
4. To maintain a stiff-legged position

8-40. You have climbed a pole to the desired height and have positioned your feet so that the left foot is slightly above the right and slightly bent. You are now ready to secure the safety belt. What is your first move?

1. Unsnapping one end of the safety strap
2. Wrapping your right arm around the pole
3. Crooking your left arm around the pole
4. Grasping one end of the safety strap with your left hand

8-41. After you have heard the snapping sound indicating that the safety strap is secured to the D-ring, what should you do next?

1. Release your left arm from the pole
2. Check your tool belt for the tools you will need
3. Look at the snap to make sure it is secured to the ring
4. Test the strap with your weight

8-42. A striker who is about to climb a newly set pole checks his body belt and safety strap, slips a line wrench and a line hammer into the tool loops on his body belt, and begins to climb. What other steps should the striker have taken before climbing the pole?

1. He should have tested the pole, and he should have checked his climbers
2. He should have taken a handline up to pull up his line wrench and hammer, and he should have tested the pole with a pike pole
3. He should have checked his climbers, and he should have carried his tools in his hand
4. He should have placed all his tools in a canvas bag hooked to his body belt, and he should have checked his climbers

8-43. When working on a crossarm near the top of a pole, you should place the safety strap around the

1. pole, just under the crossarm
2. pole, just above the crossarm
3. pole, just under the crossarm on one side and over it on the other side
4. crossarm brace

8-44. When giving pole-top resuscitation to an electric shock victim, you should provide extra support to the victim's body by

1. bringing your safety strap up between his legs
2. attaching his safety strap to your D-rings
3. attaching your safety strap to his D-rings
4. placing your safety strap around both the victim and the pole

8-45. Unlike the artificial respiration administered to a victim in the prone position, the pole-top resuscitation method uses

1. a cycle frequency of approximately 12 times per minute
2. continued repetition of cycles until the victim regains consciousness or is pronounced dead
3. repeated pressure against the abdomen
4. steady rhythm of repeated movements

8-46. What treatment should you give to an electric shock victim as soon as he regains consciousness?

1. Wrap him in a blanket and keep him lying quietly
2. Get him to swallow some whiskey or some hot coffee
3. Force him to stand up and move around
4. Place him in a sitting position until help arrives

Learning Objective: Point out practices in raising and mounting crossarms and stringing and tying in conductors.

8-47. Assume that you have mounted a crossarm on a pole. After you set the pole, what steps complete the crossarm installation?

1. Leveling the crossarm and fastening the crossarm braces to the pole only
2. Leveling the crossarm and tightening the through-bolt only
3. Tightening the through-bolt and fastening the crossarm braces to the pole only
4. Leveling the crossarm, fastening the braces to the pole, and tightening the through-bolt

8-48. Normally the conductors are taken from a reel which is

1. mounted on a freely revolving axle
2. held solidly in place
3. rolled over the ground
4. placed on its side and free to turn

8-49. When a crew is stringing several spans at once, how are the wires initially sagged?

1. Less on one end nearest the cable reel and more on the other end
2. Less on the end farthest from the cable reel and more on the cable reel end
3. To the correct sag in a span on either end of the group of spans
4. To the correct sag at the center span

8-50. At 30°F, the desired sag for a 200-foot span of AWG No. 2 wire is 20 inches. In comparison, the desired sag for this span of wire at 60°F is

1. 10 inches or less
2. between 10 and 15 inches
3. more than 20 inches but less than 40 inches
4. the same, 20 inches

8-51. When should tie wires be placed on the conductors' insulators once the conductors are strung and sagged?

1. As soon as possible after stringing
2. After exactly 2 hours
3. After 1/2 hour to 4 hours depending upong the length of the run
4. After 24 hours regardless of size of wire or length of run

8-52. Concerning the use of tie wire in tying in conductors, which of the following statements is true?

1. Do not wrap tie wire too tightly around primary conductors or insulators
2. Always use number 2 tie wire
3. Previously used tie wires that are long enough may be reused
4. Always use annealed tie wire

8-53. What should be the minimum clearance through air between a metal insulator pin and a crossarm brace?

1. 1/2 in.
2. 1 1/2 in.
3. 3 in.
4. 5 in.

8-54. Lag screws may be driven into place when the entire length of the screw is used.

Learning Objective: Indicate types of radio interferrece produced by powerlines.

In items 8-55 through 8-57, select from column B the type of interference that results from the cause in column A.

	A. Causes	B. Types of Interference
8-55.	Nonlinear rectification in a corroded connection	1. Corona
		2. Cross modulation
8-56.	Localized excessive voltage stress	3. Spark discharge
8-57.	Ionization of the air when the voltage gradient exceeds a critical value	4. Eddy currents

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Learning Objective: Identify operating principles and installation practices for distribution transformers.

8-58. A dry-type transformer is cooled by transfer of heat from the transformer to air surrounding it.

8-59. In an oil-filled distribution transformer with a corrugated metal case, the corrugations increase the ability of the unit to dissipate heat to the air. The oil serves to

1. reduce eddy currents
2. lubricate the moving parts
3. carry the heat from the coils to the surface of the case
4. provide a better path for electromagnetic flux than air provides

8-60. Which method of mounting a small transformer should you use if the latest in mounting gear is at hand?

1. A single crossarm method
2. A double crossarm installation
3. A two-pole mounting platform
4. One pole using through-bolt bracket suspension

● When answering items 8-61 and 8-62, assume that a secondary is wired as illustrated in figure 8B and the accidental connection, as shown, was due to a live primary line falling on a secondary service drop wire.

8-61. At the time of the accident, what was the voltage on the appliance and why?

1. Zero volts, because the voltage short would cause the associated substation circuit breaker to open
2. 110 volts, because the secondary of the transformer is wired in series
3. 220 volts, because the neutral is wired to ground at the substation
4. 2,300 volts, because there is no voltage or current path to ground

8-62. What action, if any, must be taken to prevent injury to persons and damage to property in the event of this type of an accidental connection?

1. Install fuses in the transformer secondary
2. Install a grounded ivre at the service switch to the neutral wire and the box
3. Install fuses in the transformer secondary hot wires
4. None

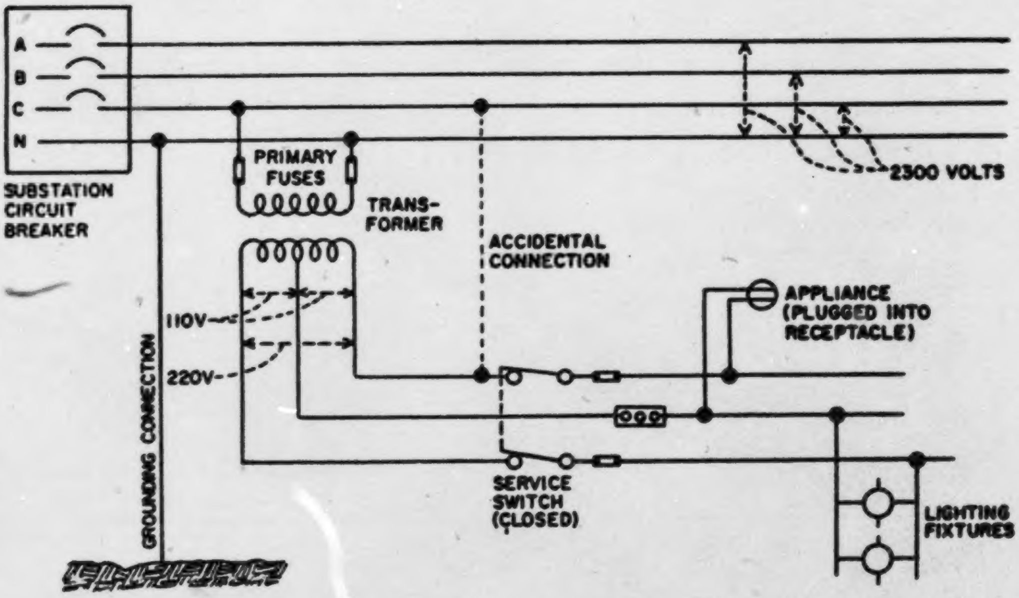
A
B
C
N
SUBSTATION CIRCUIT BREAKER
PRIMARY FUSES
TRANSFORMER
2300 VOLTS
ACCIDENTAL CONNECTION
APPLIANCE (PLUGGED INTO RECEPTACLE)
110V
220V
GROUNDING CONNECTION
SERVICE SWITCH (CLOSED)
LIGHTING FIXTURES

Figure 8B

8-63. Assume that a ground rod has been installed to ground the tanks of a pole-mounted transformer. The rod was located 4 inches from the base of the pole, and the top of the rod was 6 inches below ground level. The ground wire was run down the pole, stapled to the pole, and connected to the ground rod. This installation was unsuitable because the ground

1. rod was too close to the pole
2. rod was driven too far down
3. wire was stapled to the pole
4. wire was not protected from mechanical damage

8-64. What is the coil voltage of a transformer connected wye-wye when the primary voltage is 2400/4160?

1. 2,200
2. 2,400
3. 4,090
4. 4,160

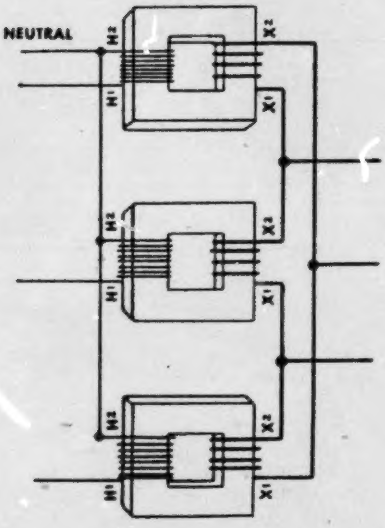

Figure 8C

8-65. The transformers in figure 8C are connected

1. delta-delta
2. delta-wye
3. wye-delta
4. wye-wye

8-66. What type of connection is made for three-phase power loads if one of three single-phase transformers in a bank fails?

1. Delta-delta
2. Open-delta
3. Single-phase
4. Two single-phase transformers in parallel

8-67. One of three 37.5-kVA transformers connected delta-delta is removed from a bank which normally produces 115.5 kVA. The remaining two are connected open-delta. What is the approximate amount of power that is now available without overloading the transformers?

1. 50.0 kVA
2. 65.0 kVA
3. 75.0 kVA
4. 96.5 kVA

8-68. You have connected three single-phase transformers delta-wye for both light and three-phase power. Which of the following voltage combinations is now possible?

1. Single-phase from only one transformer and three-phase from all three
2. Single-phase and three-phase from all three
3. Single-phase from each transformer and three-phase from all three together
4. Single-phase from one transformer and three-phase from the other two

8-69. Which of the four secondary wires can be used for 110-volt single-phase loads after three single-phase transformers are connected delta-wye for both single-phase lights and three-phase power?

1. Any two of the phase wires
2. One of the phase wires and the neutral
3. Any two phase wires and the neutral
4. Either one of two particular phase wires and the neutral

Assignment 9

Overhead Power Distribution (continued); Underground Power Distribution; Communications Systems

Textbook NAVEDTRA 10636-H: Pages 350-397

Learning Objective: Indicate operating principles of street lighting circuits and techniques of circuit troubleshooting.

9-1. In a series street-lighting circuit, power is supplied by a transformer which maintains a constant

1. voltage
2. current
3. power factor

9-2. In street lighting, why is a ballast used with the mercury vapor lamp?

1. To limit current to the lamp
2. To supply the lamp with a negative voltage
3. To provide a pilot circuit to the lamp for external control
4. To enable more than one lamp to be lighted

9-3. Which of the following conditions is likely to cause the lamps of a series circuit to burn dimly?

1. Defective lamp or lamps
2. Defective regulator
3. Blown primary fuse
4. Overloaded regulator

9-4. In sectionalizing an open-loop series circuit, you find that the lamps in the shorted section of the circuit will not light up, but the lamps in the rest of the circuit will light up. Which of the following statements about this series circuit is TRUE?

1. Opens exist in both sections
2. The open is in the shorted section
3. The open is in the section that was not shorted out

Learning Objective: Point out principles of identifying and arranging obstruction lights.

9-5. What should be the color and minimum candle-power of obstruction lights?

1. Red, 10 candlepower
2. Aviation red, 100 candlepower
3. Blue, 10 candlepower
4. Blue, 100 candlepower

9-6. In addition to lights at the top, how many intermediate sets of lights will be needed for a vertical structure 450 feet tall?

1. One
2. Two
3. Three
4. Four

9-7. What is the maximum distance between lights on overhead wiring that is located 3,000 feet from an airfield?

1. 50 ft
2. 150 ft
3. 300 ft
4. 600 ft

Learning Objective: Indicate construction features of manholes, ducts, and trenches.

9-8. Which of the following manholes should the CEs find most suitable for installing cables without bending them sharply and damaging their lead sheaths and without being cramped for head room?

1. 5-ft deep circular manhole
2. 5-ft deep rectangular manhole
3. 7-ft deep elliptical manhole
4. 9-feet deep square manhole

9-9. Water drainage from each manhole should be provided by means of

1. ducts that slope away from the manhole
2. pumps installed at the manhole
3. a central drain hole, a drain line, and a sump for the manhole
4. a series of drainage holes bored in the deck of the manhole

9-10 Which of the following tools should be used to turn down the ends of Orangeburg tile ducts which have been cut to an odd length and are to be joined?

1. Hacksaw
2. File
3. Field tooling lathe
4. Hacking knife

9-11. What is the minimum depth below ground level that duct work should be placed?

1. 1 ft
2. 18 in.
3. 2 ft
4. 30 in.

Learning Objective: Identify practices in cable pulling.

9-12. To aid in performing a future task, which of the following actions should the crew perform as it connects the lengths of duct?

1. Allowing space for at least 3 inches of cement under the lowest duct line
2. Laying-in a pulling wire
3. Sloping the duct line from the center of the run to the manholes
4. Installing only six lines of ducts between manholes

9-13. You are preparing a cable for pulling. After securing the bolt to the end of the cable, the end of the cable is made watertight by

1. sweating (soldering) the wire ends to the wire binder
2. beating the ends of the cable over the solder sweat
3. wrapping tape between the bolt and the lead sheath
4. closing the sheath down against the bolt and wiping between the sheath and bolt with melted solder

9-14. The reel of textbook figure 11-8 is properly positioned. What is likely to happen as cable is pulled from the reel into the manhole?

1. The protective boot will fall into the manhole
2. The bend in the cable will reverse itself
3. The reel will turn clockwise
4. The reel jacks will slide toward the edge of the manhole

9-15. Suppose cable is being winched into a duct from a reel that is in sight of the winch operator. Which of the following is a duty for the operator?

1. Inspecting the cable for defects as it pays off the reel
2. Seeing that the cable pays off the reel properly
3. Sending signals to the man who guides the cable into the duct
4. Making sure the winch line winds onto the reel properly

Learning Objective: Recognize principles and techniques of splicing cable in an underground power distribution system.

● The following information, and the table below, are to be used as needed, to answer items 9-16 through 9-27. An electrical system is to be installed in an airfield. Manholes and handholes are to be constructed on the jobsite by a crew of Builders. As a Construction Electrician, you are a member of the electrical crew. You will be working with a single-conductor, 500-MCM, lead-covered, rubber-insulated cable. All cable splicing will take place in the manhole or handholes.

CODE NO	SIZE OF LARGER CONDUCTOR AWG OR MCM	DIMENSIONS (INCHES)				
		LEAD SLELVE		CON-NECTOR LENGTH	A	B
		I D	LENGTH			
1	6	1 ½	9	1 ½	3 ½	1
2	3	1 ½	9	2	3 ½	1 ⅛
3	2	1 ½	9	2	3 ½	1 ⅛
4	2/0	2 ½	11	2	4 ½	1 ¼
5	4/0	2 ½	11	2 ½	4 ½	1 ½
6	350	2 ½	11	2 ½	4 ½	1 ½
7	500	2 ½	12	3	4 ¾	1 ¾
8	750	3	13	3 ½	5	2
9	1500	3 ½	18	5	5 ¾	2 ¾
10	2000	3 ½	18	6	6 ¼	3 ¼

Straight joint, 5000-volt rubber-insulated.

9-16. All water is removed from a manhole before cable splicing begins in order to prevent

1. methane gas from accumulating
2. splices from absorbing moisture while they are being made
3. working conditions from becoming unsafe

9-17. When do you place the scraped and coated sleeve on one of the cable ends?

1. Right after smoothing the inside of the sleeve
2. Just prior to tinning the connector
3. Right after soldering the connector to the conductors
4. Just prior to reinsulating the joint

For items 9-18 and 9-19, refer to figure 9A.

9-18. What is the distance of A?

1. 3 1/2 in.
2. 4 1/2 in.
3. 4 3/4 in.
4. 5 3/4 in.

9-19. What is the distance of B?

1. 1 in.
2. 1 1/4 in.
3. 1 1/2 in.
4. 1 3/4 in.

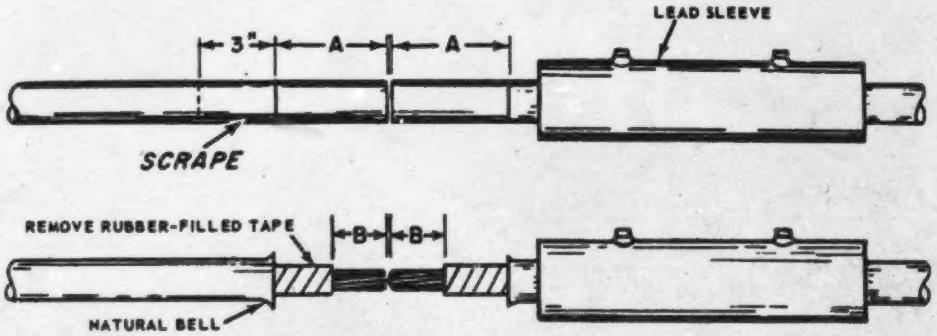

Figure 9A

9-20. At this stage, you have placed the split sleeve connector over the conductors. Cotton tape is then wrapped around the ends of the insulation in order to keep the insulation form melting or catching fire. Now, how do you permanently affix the connector to the conductors?

1. By crimping the connector onto the conductors
2. By soldering with a soldering iron and wire solder
3. By soldering with a butane torch and bar solder
4. By pouring molten solder over the connector

9-21. Copper, solder, and lead filings or grains should be removed from the insulation and the bare metal at the area of the splice by

1. scraping with a flat file
2. pouring molten lead or solder over the area
3. pouring hot taping oil over the area
4. spraying the area with compressed air

9-22. The last taping step in completing the splice involves the use of

1. friction tape, half-lapped, built up in two layers
2. rubber tape, half-lapped, built up 5/16 inch over the connector
3. friction and rubber tape, half-lapped built up 5/8 inch over the connector and cable insulation
4. rubber and friction tape, half-lapped built up 5/16 inch over the connector conductors and cable insulation but tapering down at the ends of the wrap

9-23. You are now ready to wipe the lead sleeve to the cable. The lead sheath is scraped clean and stearine flux is applied for a distance of 3 inches back on each cable. After you center the sleeve over the splice area, what is the next step?

1. Dressing the ends of the sleeve to form a tight fit around the cable sheath
2. Wiping the sleeve to the cable sheath by the stick-and-torch method
3. Wiping the sleeve to the cable sheath by the hot-lead ladling method
4. Applying paper pasters on the sleeve and the cable sheath

9-24. Assume that you have performed all the proper operations in preparation for wiping a joint. Then you prepare the wiping metal. If you have no thermometer, how can you tell when the metal is the proper temperature and ready to be used?

1. When the metal takes on a bluish color
2. When a paster paper inserted into the metal and removed immediately comes out scorched and about to burst into flames
3. When the metal pours easily from a ladle
4. When a small stick of pressboard inserted in the metal and removed immediately turns black

9-25. The joint must be tinned in order for the wipe to come out properly. Tinning is accomplished by

1. pouring solder over the joint until it flows easily from the joint
2. placing a small furnace under the joint until the solder sputters when dripped on the joint
3. directing a gasoline torch along the side of the joint until the solder flows easily
4. directing an acetylene torch over the joint until the solder flows easily on the joint

9-26. If you are experienced at the job of wiping a lead sleeve to a lead cable sheath, you may find that the wipe is improperly shaped, or later, when it is placed under an air pressure test, that it leaks. In the case of a misshaped wipe, what is your best corrective action?

1. Using a gasoline torch to reshape or seal the sleeve wipe
2. Using a soldering iron to repair the sleeve discrepancies
3. Removing the sleeve and starting over
4. Melting the wiping lead off by pouring melted lead over it and making a new wipe

9-27. You connect the pressure gage to the lead sleeve to make an air pressure test. What should be the pressure of the air you pump into the sleeve?

1. 6 psi
2. 15 psi
3. 25 psi
4. 50 psi

9-28. If a splice is intended to connect cables that are to carry 10,000 volts, what splicing step differs from the corresponding step made on a 4,160-volt line?

1. The insulation has to be cut differently
2. The splice area is purged of all air and moisture with hot oil and tightly wrapped oil-soaked varnished-cloth tape
3. A completely different type of split copper connector is installed
4. The split copper connector is bonded to the conductors differently

9-29. When finishing a cable splice with resin or similar compound, you check to see that the mold is long enough to cover the sheath on each end by at least

1. 1/4 inch
2. 1/2 inch
3. 3/4 inch
4. 1 inch

9-30. Cable tags should identify a cable and its voltage. At which of the following places should tags be attached to the cable?

1. Each manhole and cable termination point
2. Each manhole only
3. Each termination point only
4. Each cable test point

9-31. What should you do to reduce voids in taping a splice?

1. Half lap and slant the tape in the connector area and at the splice ends
2. Stretch the tape in the connector area and at the splice ends
3. Tape the connector area and splice end to build up these areas first
4. Use a forming tool in the connector area and at the splice ends

9-32. While injecting resin slowly into a tape-cast splice with a pressure gun, you should stop injecting when the

1. resin runs out of the vent in the splice and all air escapes
2. splice doubles in size
3. gun pressure is unable to overcome the built-up pressure in the splice

9-33. Gas fumes are the greatest danger to personnel working in a manhole. What precaution must be taken to avoid this danger?

1. Wear a gas mask
2. Make a gas test before starting to work and ventilate the manhole if necessary
3. Take a power blower into the manhole and operate it at all times for ventilation
4. Lower an oxyacetylene torch into the manhole before entering to burn off the gas fumes

9-34. Which of the following practices is recommended when handling hot oil or lead?

1. Walk with a shuffling step when carrying a kettle of hot liquid; locate the furnace far enough away from manholes so that hot metal will not splash into them
2. Move quickly but carefully when carrying a kettle of hot liquid; locate the furnace near working spaces so the kettle will not have to be carried far
3. Move with long, slow steps when carrying a kettle of hot liquid; locate the furnace away from all working spaces to minimize danger of spills
4. Always carry a kettle on a kettle carrier, making sure the path is clear; locate the furnace near the working space so the hot liquid need not be carried far

Learning Objective: Recognize fundamentals of lighting an airfield.

In items 9-35 through 9-38, select from column B the location of lights having the color in column A.

	A. Colors		B. Locations
9-35.	Red	1.	At the ends of the runway
9-36.	White (clear)		
9-37.	Blue	2.	At the runway landing area
9-38.	Green	3.	On obstructions and hazards in and around the airport
		4.	Along the edges of taxiways

9-39. The barrettes used for military runway approach lighting are arrays of lights level with the runway. Each array consists of

1. one steady light and five flashing lights
2. five flashing lights
3. five steady lights
4. five green lights and five blue lights

9-40. What is the main factor in lighting an airfield?

1. Lighting the approaches
2. Sequential lighting
3. Lighting the runways
4. Expedient lighting

9-41. Failures of the underground wiring used for airfield lighting can usually be predicted and prevented by

1. special inspections after heavy rains or severe weather
2. periodic megger tests
3. periodic tests of regulators and transformers
4. frequent inspections of fixtures and pull-pits

Learning Objective: Recognize operating principles of a telephone system and techniques of installing telephone lines.

9-42. In addition to a transmitter and a receiver at each of two locations, a single telephone circuit contains

1. a means of signaling
2. a source of electrical energy
3. a wiring circuit
4. All the above

9-43. All of the following features are found in the telephone transmitter EXCEPT a

1. chamber packed with small grains of carbon
2. flexible metallic diaphragm
3. U-shaped magnet
4. movable carbon disk

9-44. Sound waves cause the resistance in series with a telephone battery to vary. This is done by using the energy of the sound to

1. move an electromagnet in a magnetic field
2. compress carbon granules between two electrodes
3. move a permanent magnet inside a coil
4. induce a voltage in an induction coil

9-45. Ringing current for telephone installations that use local battery sets is furnished by

1. dry cell batteries
2. transformers
3. hand-operated generators
4. wet cell storage batteries

9-46. The induction coil in a telephone set serves as a

1. step-up transformer for transmitter signals only
2. step-up transformer for transmitter and receiver signals
3. stepdown transformer for signaling current and receiver signals
4. stepdown transformer for transmitter signals

9-47. What practical purpose is served by the connection between the primary and secondary of the induction coil in a typical field telephone set?

1. The number of turns in the primary coil is reduced
2. The number of turns in the secondary coil is reduced
3. Fewer handset cord conductors are needed
4. Voice currents from the transmitting to the receiver in the same set are eliminated

9-48. The magnetic field of the hand-operated generator used in telephone circuits to provide signaling service is provided by excitor coils.

9-49. The back-and-forth motion of the ringer armature in a telephone set is produced by

1. breaker contacts on the clapper
2. current alternations in the ringing signal
3. a spring switch on the magneto crank
4. a spring-mounted contact on the hook switch

9-50. A long telephone transmission line is one whose length equals or exceeds the wave length of the transmitted signal.

9-51. You can reduce the attenuation in a long field wire line by increasing the

1. resistive load across the line
2. series capacitance of the line
3. shunt inductance across the line
4. series inductance of the line

9-52. When used in conjunction with a 2-wire circuit in an emergency installation, a 1-wire ground return circuit proves to be especially sensitive to

1. attenuation
2. inductive interference
3. capacitive coupling
4. mutual induction

9-53. If you run field wire on poles that carry open wire lines, you must be certain that

1. greater-than-normal sag is left in the field wire
2. the field wire is placed above the open wire
3. less-than-normal sag is left in the field wire
4. the field wire is placed below the open wire

9-54. Assume that you wish to link a newly installed exchange at an advanced base with a nearby exchange that was set up earlier. Which of the following cables will you use for this purpose?

1. Post cable
2. Toll cable
3. Exchange cable
4. Trunk cable

9-55. When you run a telephone cable on poles, you will usually need a cable car to

1. install the suspension strand
2. pull the cable into position
3. install the cable rings and dragline
4. tension the suspension strand

9-56. When installing telephone lines at an advanced base, you will normally use pole-mounted terminal boxes to

1. join cable stubs to distribution frames
2. join buried cables to overhead open wires
3. connect drop wires to main cable stubs
4. terminate cables at exchanges

Assignment 10

Communications Systems

Textbook NAVEDTRA 10636-H: Pages 398-427

Learning Objective: Identify operating principles of a telephone switchboard.

10-1. Incoming lines to a switchboard office terminate on

1. switchboard terminals
2. distribution frames
3. terminal bus bars
4. connector banks

10-2. Terminals on the vertical side of a type-B switchboard are used to connect

1. outside lines to jumpers
2. outside lines to line jacks
3. line jacks to jumpers
4. jumpers to fuses and arresters

10-3. Automatic signalling in a common battery line circuit is accomplished by the use of

1. relays
2. series-connected lamps
3. parallel-connected lamps
4. cutoff jacks

10-4. The universal cord circuit is commonly used in military switchboards because it permits

1. operation of common battery and local battery sets through a single exchange
2. common battery operation of local battery sets
3. operator selection of common battery or local battery operation
4. automatic relay selection of called telephones

10-5. Assume that several conversations are taking place through a switchboard at one time. To select and cut into one of these circuits, the operator must use a

1. plug and hook switch
2. plug
3. lever switch
4. plug and key switch

10-6. Switchboard ringing machines generate an output frequency that is the equivalent to

1. 10 Hz
2. 20 Hz
3. 30 Hz
4. 40 Hz

Learning Objective: Recognize practices to the installation of a telephone subset.

10-7. When you install a telephone subset in a building, you must place a lightning arrester or other protective device between the

1. main line and terminal box
2. terminal box and drop wire
3. drop wire and connecting block
4. connecting block and instrument

10-8. Why is a drop wire clamp used on a drop wire?

1. To support the cable stub where it joins the drop wire
2. To keep the weight of the pole-to-building run from straining the rest of the drop wire
3. To keep the pole-to-building run of drop wire from sagging
4. To support the drop wire where it runs along the outside of the building

10-9. Which of the following devices is used to protect drop wire where it enters a building?

1. Screw eye
2. C-knob
3. Porcelain tube
4. S-knob

10-10. In grounding a lightning arrester, you should, when possible, connect its center terminal to a

1. gas pipe
2. lightning rod
3. cold water pipe
4. sprinkler pipe

10-11. You are to connect a drop wire directly to an open main run wire. What type of support should you use for the drop wire when training it along the crossarm of a pole?

1. C-knob
2. Insulated screw eye
3. Bridle ring
4. Drive ring

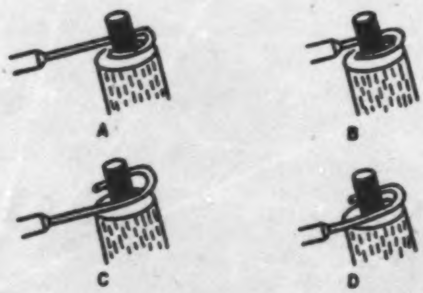

Figure 10A

10-12. Which drawing in figure 10A shows the proper way to connect a drop wire to a binding post?

1. A
2. B
3. C
4. D

10-13. The wire which must always be connected to the right-hand terminals of protectors and connecting blocks is the

1. ringer wire
2. hook wire
3. tracer wire
4. tip line

10-14. You can identify the hot or negative wire at any point in interior telephone wiring by the

1. raised thread in the outer covering
2. red tracer thread
3. ridged insulation
4. tinned copper conductor

10-15. If several telephones connect to a single line, you will probably have to install a bell circuit for signaling recipients of calls. How is the signaling circuit related to the multiset telephone wiring?

1. The telephone ringers are controlled by an external power source and pushbuttons
2. External signaling devices and control buttons receive power from the telephone battery
3. External pushbuttons control ringing of the instruments
4. The signaling circuit is completely independent of the telephone wiring

---

Learning Objective: Indicate fundamentals of field telephone systems and techniques of installing, operating, maintaining, and troubleshooting them.

10-16. Which of the following items of military telephone equipment includes its own 120-volt a-c power source?

1. TC-2
2. TTC-7A
3. SB-22/PT
4. TA-312/PT

10-17. The SB-22A/PT switchboard gets its power from

1. a local 24-volt d-c generator
2. local batteries
3. a 110-volt single-phase line
4. a 110-volt single-phase generator

10-18. The 12-line switchboard is designed to interconnect

1. common-battery telephone lines for units up to and including a battalion
2. common-battery telephone lines for units smaller than a battalion
3. local-battery telephone lines for units smaller than a battalion
4. local-battery telephone lines for units up to and including a battalion

10-19. The line signal for an SB-22A/PT switchboard is located in the

1. operator's pack
2. line pack
3. generator section
4. front cover

10-20. What device signals the operator of a local-battery telephone system?

1. Ringing machine
2. Buzzing machine
3. Electromechanical line signal
4. Solenoid-actuated click device

10-21. The indicator ball on a 12-line switchboard is restored by

1. an electromechanical device connected to the drop
2. an electromagnet connected to the jack
3. the insertion of the operator's cord plug into the line jack
4. the switchboard operator, manually

10-22. The operator of an SB-22A/PT switchboard can interconnect phones by using the

1. answering cord and a calling cord
2. answering cord and a talk-ring cord
3. operator's cord pack and a line drop
4. operator's cord pack and a line pack

10-23. The purpose of the ringing equipment on the operator's pack of the 12-line switchboard is to permit the operator to connect ringing current to

1. the calling telephone
2. the called telephone
3. either the calling or the called telephone
4. the alarm equipment

10-24. The operation of the alarm equipment on the operator's pack of the 12-line switchboard indicates to the operator that

1. one of the line pack drops has operated
2. a particular station is signalling the switchboard
3. one of the stations is inoperative

10-25. In a properly installed SB-22A/PT switchboard, how many pairs of BA-30 (1.5-volt) dry cells are used and what voltage does each pair supply?

1. 2; 6 v
2. 2; 3 v
3. 1; 3 v
4. 1; 1.5 v

10-26. When should you make the ground connections on the 12-line switchboard?

1. After connecting the telephone wires and installing the batteries
2. After connecting the telephone wires but before installing the batteries
3. Before connecting the telephone wires
4. Before testing the line packs and operator's pack

10-27. Where should the top of the ground rod for the 12-line switchboard be with respect to the surface of the ground?

1. 3 in. above the surface
2. 6 in. above the surface
3. 3 in. below the surface
4. 6 in. below the surface

10-28. How can two 12-line switchboards be arranged to handle as many as 29 lines?

1. By utilizing additional field phones for the extra service
2. By installing the smaller, more modern line packs
3. By installing two of the served phones on one pair of binding posts
4. By removing the operator's pack from one switchboard and installing five line packs

10-29. When two 12-line switchboards are stacked, each board receives its power from

1. its own dry-cell batteries
2. the dry-cell batteries of the other set
3. the set with 12 line packs
4. the set with 17 line packs

● Items 10-30 through 10-35, refer to the troubleshooting procedures for a 12-line switchboard.

10-30. The most frequent cause of improper functioning of the switchboard is

1. night alarm switch left on
2. dirt or corrosion on the telephone jack springs
3. loose wire connections
4. weak dry cells

10-31. The user of a particular telephone cannot signal the operator because the drop on his line does not function. If everything else functions normally, the trouble is probably caused by

1. rundown batteries
2. a defective handset-headset
3. a defective line pack
4. a defective operator's pack

10-32. The operator cannot talk to or receive calls from any of the telephone users. Which of the following could cause this problem?

1. A defective handset-headset
2. A defective operator's pack
3. A defective line pack
4. Each of the above

10-33. When two telephone users cannot communicate with each other, but the operator can communicate with each user separately, the trouble is probably caused by

1. rundown batteries
2. a defective handset-headset
3. a defective operator's pack
4. a defective line pack

10-34. If the operator cannot ring any field telephone and everything else functions normally, the trouble is probably caused by

1. rundown batteries
2. a defective handset-headset or rundown batteries
3. a defective operator's pack
4. a defective operator's pack or line pack

10-35. The operator's alarm fails to operate when the drop of a line pack indicates that someone is calling the operator. Which of the following could be causing the trouble?

1. Defective line pack
2. Defective operator's pack
3. Rundown batteries
4. Each of the above

10-36. If the internal batteries are not used, what external source is required to power the TA-312/PT?

1. 3 v, alternating current
2. 6 v, alternating current
3. 6 v, direct current
4. 10 v, direct current

10-37. Which of the following maintenance requirements is performed weekly rather than daily?

1. Checking the handset for proper mechanical action
2. Checking the battery compartment for general deterioration
3. Checking the buzzer
4. Cleaning exterior surfaces

In items 10-38 through 10-40, select from column B the hookup system for the EE-8 that has the features in column A.

	A. Features	B. Hookup Systems
10-38.	Has ranges up to 360 miles and uses hand generator for signaling	1. CB switchboard
10-39.	Has ranges up to 72 miles and uses hand generator for signaling	2. LB switchboard
10-40.	Uses local batteries for transmissions and common batteries for signaling	3. Point-to-point
		4. Local-to-point

10-41. In what operating state should you leave the handset if the handset is momentarily not in use?

1. Switch in "Off" position, batteries removed
2. Switch in "Off" position, batteries left in
3. Switch in "On" position, batteries removed
4. Switch in "On" position, batteries left in

Learning Objective: Explain the operation and identify the components of an automatic telephone exchange of the type used at advanced bases.

10-42. The switchboard cord circuits of a manual telephone system are replaced in the dial system by

1. a dial mechanism in the subset
2. switching mechanisms electromechanically operated by remote control
3. relays in the subset base
4. pole-mounted line selectors

10-43. Which of the following voltages will serve as a source voltage for operating efficiently the equipment of a step-by-step, common-battery, automatic dial telephone?

1. 18-volt a-c
2. 18-volt d-c
3. 48-volt a-c
4. 48-volt d-c

10-44. Which of the following switches serves as the basic unit of the step-by-step system?

1. Linefinder
2. Connector
3. Strowger
4. Selector

In items 10-45 through 10-47, select from column B the function of the component in column A.

	A. Components	B. Functions
10-45.	Linefinder	1. Extends the transmitter to the connector by the first digit dialed
10-46.	Connector	2. Makes the extension between the transmitter and receiver
10-47.	Selector	3. Finds the calling station
		4. Controls the linefinder

10-48. What factor determines the number of finder-connector links in a basic finder-connector system?

1. Number of phones of any type
2. Number of phones equipped to originate calls
3. Capacity for simultaneous calls
4. Extent of executive cut-in service

10-49. Concerning the impulses to the switching mechanism, the number dialed on a telephone determines their

1. number
2. intensity
3. duration
4. rate

10-50. In a 1,000-line system, the dial tone indicates that a connection has been made from

1. calling telephone to receiving telephone
2. finder to connector
3. finder to selector
4. selector to receiving telephone

10-51. The procedure pattern of a dial system of more than 10,000 lines is the same as that of a 1,000-line system, except that

1. two dial tones are heard
2. an additional selector is necessary
3. the number of linefinders is doubled
4. one set of wipers is used

Learning Objective: Identify functions of the basic components of a crossbar switching system.

10-52. What component of a crossbar office transmits numbers, in special codes, that other offices are set up to receive?

1. Marker
2. Originating register
3. Sender
4. Number group frame

10-53. A telephone line which begins and ends in the same central office is called a/an

1. outgoing trunk
2. incoming trunk
3. interoffice trunk
4. intra-office trunk

10-54. The movement of a horizontal and vertical bar in a crossbar switch closes a set of

1. relays
2. crosspoints
3. electromagnets
4. originating registers

10-55. The component in a switching network which records the numbers dialed is the

1. marker
2. incoming register
3. orginating register
4. outgoing sender

10-56. What component of a switching network is an electrical telephone directing?

1. Marker
2. Incoming register
3. Originating register
4. Number group frame

Assignment 11

Interoffice Communications Systems; Telephone Cable Splicing; Administration

Textbook NAVEDTRA 10636-H: Pages 429-469

Learning Objective: Recognize operating principles and installation and troubleshooting procedures of interoffice communications equipment.

11-1. You are installing an intercom system using a master station with a capacity of 6 remote speaker-microphone units. If 3 of the remote units are made into master stations, how many remote speaker-microphone units may be installed?

1. 3
2. 5
3. 7
4. 9

11-2. The pilot light is iluminated on the master station of an intercom system when

1. a selector switch is in the ON position
2. the talk-listen switch lever is in the TALK position
3. an annunciator springs outward
4. the equipment is turned on

11-3. Under normal operating conditions of an intercom system, the master station talk-listen switch lever is kept in what position?

1. TALK
2. LISTEN
3. OFF
4. IDLE

11-4. When the operator of an interoffice communications system originates a call from the master station to a party at a remote station, he puts the switch for the remote station in the ON position, depresses the talk switch, and speaks to the party.

11-5. When an intercom system is installed, No. 22 to No. 19 twisted pair wire must be used for the

1. voice lines
2. annunciator lines
3. voice lines and annunciator lines
4. voice lines and the annunciator lines when the stations are farther than 4,000 feet apart

11-6. All connections of the master station unit of an intercom system should be made in or at the

1. speaker microphone
2. selector panel
3. junction box
4. pushbutton terminal block

11-7. When should the circuit wiring of an intercom system be checked for maximum resistance?

1. Before the wiring is installed
2. After the wiring is installed, but before the connections are made
3. After the wiring is installed and the connections are made
4. After the system has been in operation for approximately 10 hours

11-8. The feel operation is used to

1. detect dirt on the equipment
2. determine whether moving parts move freely
3. locate broken components
4. locate overheated components

11-9. What is the most common cause of failure at master stations?

1. Burned-out resistor
2. Faulty tube
3. Poorly soldered connection
4. Shorted transformer

11-10. Assume that you are moving a defective selector switch from an intercom master station. What should you do before unsoldering the leads connected to the switch?

1. Clean the solder joint
2. Check the leads for damage
3. Remove the insulation from the end of the leads
4. Tag the leads

Learning Objective: Recognize techniques of maintaining and troubleshooting communications systems.

11-11. Overheating and gassing of storage battery cells during charging is a common indication of

1. excessive charging current
2. excessively low specific gravity
3. simultaneous discharging by internal leakage currents
4. poor terminal connections

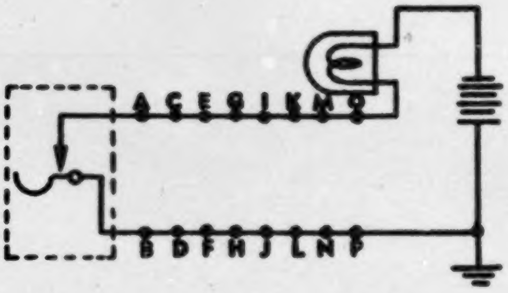

Figure 11A

Items 11-12 through 11-14 are based on the telephone circuit shown in figure 11A.

11-12. Assume that the line is grounded between points M and K. You should hear a click through your test telephone when you connect it in series with points

1. A and C
2. E and G
3. I and K
4. M and O

11-13. Assume that the signal lamp at the switchboard lights continuously and the circuit is noisy. Where do you first place your test telephone to trace the location of the trouble?

1. In series with points M and O
2. In series with points N and P
3. Across points O and N after disconnecting N and P
4. Across points M and P after disconnecting M and O

11-14. Assume that you are tracing a short in the telephone circuit. If you are following standard tracing procedure and the short is between points C-E and D-F, the first time that you should hear no click through your test telephone is when you connect it in

1. series with points M and O
2. series with points F and H
3. series with points D and B
4. parallel with points A and C

11-15. You have found that the trouble with an inoperative subset circuit is not due to a malfunction in the subset itself. Where is the best place for you to begin testing to locate the trouble?

1. Base of the subset
2. Protector unit
3. Pole terminal box
4. Main distribution frame

11-16. Which of the following components of a switchboard require only monthly inspection?

1. Protector blocks
2. Shutter latches
3. Carbon blocks
4. Relays and capacitors

Learning Objective: Select the type of telephone cable to be used in a given type of installation.

In items 11-17 through 1-19, match the type of installation in column A by selecting from column B the type of telephone cable to install.

	A. Types of Installation		B. Types of Cable
11-17.	Switchboard	1.	Lead-covered cable
11-18.	Underground in conduit	2.	Tape-armored cable
11-19.	Aerial	3.	Silk and cotton cable
		4.	Polyethylene cable

Learning Objective: Identify principles and techniques of splicing lead-sheathed cable.

11-20. Assume that a CE2 splicing a cable has removed the sheath. At what point in his procedure should he clean the lead sleeve and put in on the cable?

1. After cleaning the ends of the cable
2. After preparing the sleeve for use by squaring up the ends
3. After removing the insulation from the individual wires
4. After putting the cotton sleeves on the individual wires

11-21. When a telephone cable is to be spliced, the first thing to be done is to remove a section of sheath from the end of each cable. Once the decision on how much of the sheath to remove has been made, the following steps must be carried out: (A) cleaning a 4-inch section of the remaining sheath, (B) actually splitting and removing part of the sheath, and (C) ringing the cable at the intended distance from the end. In what order are these steps taken?

1. A, C, B
2. B, A, C
3. C, B, A
4. C, A, B

11-22. Assume that a CE2 who is about to boil out the insulation where a splice is to be made does not have a thermometer capable of reading more than 350°F. When should he consider the paraffin hot enough to pour over the sheath?

1. When the paraffin forms a slight bluish ring at the edge of the pot
2. When the paraffin forms a dry ring on the outside of the pot, about 2 inches wide at the widest point
3. When a piece of paper, plunged into the paraffin and removed half a minute later, comes out brown
4. When the paraffin begins to form a dry ring on the outside of the pot

11-23. What is the advantage of the desiccant method over the paraffin boiling-out method for removing moisture from the insulation in lead-sheathed cable?

1. No objectionable fumes are produced
2. The fire hazard is eliminated
3. It is safer to use on interior splicing jobs
4. Each of the above

11-24. Which of the following factors should you consider first when identifying conductors?

1. Whether the exposed end of the cable faces toward or away from the central office
2. Geometric pattern of the cable groups
3. Number of twisted pairs in the cable
4. Problem of locating the tracer pairs in the cable

11-25. How are the color-coded groups arranged in a cable with 200 pairs?

1. 6 groups of 25, 4 groups of 8, and 2 groups of 9
2. 2 groups of 100
3. 8 groups of 25
4. 4 groups of 50

11-26. What is the purpose of a tracer pair?

1. To establish the point from which conductor count begins
2. To establish communication with a helper
3. To provide for an extra telephone outlet when new service is desired
4. To indicate which pair is to be spliced first and to provide emergency communication prior to the completion of the splice

11-27. Two pairs of wires have been selected from a cable, and are to be joined. Which of the following is the best sequence to follow when tying the wires?

1. Slip on cotton or plastic sleeves; twist wires together, and cut to proper length
2. Cut wires to proper length; strip insulation; slip on cotton or plastic sleeves; twist wires
3. Strip insulation; slip on cotton or plastic sleeves; twist wires; cut to length
4. Twist all four wires together with a half turn; cut to length and strip insulation; separate wires and slip on plastic or cotton sleeves; twist the joints

11-28. What should you do after splicing all the pairs of conductors and before sliding the lead sleeve into place?

1. Tap around the bundle lightly with a mallet, so the lead sleeve will fit the bundle properly
2. Wrap the bundle with two layers of dry muslin
3. Rearrange the spliced conductors so they will fit the lead sleeve
4. Wrap the bundle with a No. 18 wire

Learning Objective: Point out techniques of splicing silk-and-cotton insulated cable and polyethylene-insulated cable.

● Information for items 11-29 and 11-30. Assume that destruction caused by a small fire in an office building has made it necessary to replace a cable head. The textile-insulated cable to be used has enameled conductors.

11-29. When desiccant is not used, what substance is used to dry the cable before the silk insulation is removed?

1. Paraffin
2. Taping oil
3. Beeswax or a special petroleum wax
4. Paraffin or beeswax

11-30. When splicing enamel-coated wires, what must you do after removing the insulation from all the wires but before doing the actual splicing?

1. Remove the enamel from the exposed wires with long-nosed pliers or a wire scraper
2. Coat the wires with stearine to soften the enamel, then wipe them clean
3. Remove the enamel from the exposed wires by bending each wire at the desired point gently enough to crack the enamel without breaking the conductor, and then sliding the enamel off
4. Remove the enamel from the exposed wires by applying paraffin to loosen it and then sliding the enamel off

11-31. The subgroups into which you divide a basic 25-pair PIC group for laying up are referred to as

1. subpairs
2. units
3. strands
4. cores

11-32. One particular PIC wire pair group is identified with a red and blue binder. After removing the plastic sheath and the metal shield but before completely removing the binder, you must mark the wire group with

1. a tag tied to the group and stamped with its pair numbers
2. one red and one blue insulated wire wrapped around the group
3. strips of the binder

11-33. After you have made and soldered a splice in a PIC group you ordinarily cover the splice with

1. friction tape
2. plastic tape
3. a filled plastic sleeve
4. a wax-impregnated cotton sleeve

11-34. Assume that a 50-pair PIC is being spliced to another 50-pair PIC. The splice bundles will be covered with a short base enclosure. The probable layup of sleeved joints and the splice bundles arrangement will consist of

1. 2 bundles of 25 joints each
2. 2 bundles of 50 joints each
3. 2 bundles of 33 joints each and one of 34 joints
4. 2 bundles of 32 joints each and one of 36 joints

11-35. A layup of spliced conductors is made waterproof and accessible for reopening by fitting it with butyl rubber enclosure.

Learning Objective: Identify steps in the procedure for splicing plastic-sheathed cable to lead-sheathed cable.

● Items 11-36 through 11-42 concern the method for splicing a plastic-insulated cable to a paper-insulated lead-sheathed cable in a straight splice. The wires are being jointed inside a building.

11-36. The lead-sheathed cable and the plastic-insulated cable are prepared to receive the lead sleeve by cleaning the areas where the sleeve will join the cable sheaths. This cleaning is done by

1. scraping 4 inches of the lead sheath and scuffing (with sandpaper) 7 inches of the plastic sheath
2. scuffing 4 inches of the lead sheath and scraping 7 inches of the plastic sheath
3. scraping 7 inches of the lead sheath and scuffing 4 inches of the plastic sheath
4. scuffing 7 inches of the lead sheath and scraping 4 inches of the plastic sheath

11-37. In preparing the lead sleeve selected for the splice cover, you clean

1. the entire sleeve both inside and out
2. the outside of the sleeve at both ends
3. the inside of the sleeve at both ends
4. inside the sleeve at the end that goes over the PIC and outside the end that goes over the lead-sheathed cable

11-38. In the procedure for casting the plastic end seal for a cable splice, when should you move the wires back and forth slightly to aid penetration of the liquid?

1. While pouring the casting mixture into the form
2. While moving the casting form up to the casting position
3. Before preparing the casting mixture
4. After one-half of the casting mixture has hardened

11-39. The length of the twisted and soldered part of the joint connecting two conductors is within the range of

1. 7/8 to 2 inches
2. 3/4 to 1 3/4 inches
3. 1 3/8 to 1 3/4 inches
4. 1 1/2 to 2 3/4 inches

11-40. What substance is placed in the conductor splice area just prior to the first wrapping operation?

1. Oil
2. Wax
3. Sealing compound
4. Desiccant

11-41. Before soldering, the shield in the PIC should be connected to the lead sheath of the paper-insulated cable by

1. wrapping it completely around the splice area and around the lead sheath
2. bringing it straight across the splice area and around the lead sheath
3. wrapping it loosely around the splice area and attaching it under the lead sheath
4. threading it between the wires in the splice area and attaching it to the lead sheath

11-42. How is the wire cloth wrap secured to the plastic sheathing of the PIC?

1. It is taped on
2. It is soldered where the sheath and cloth overlap
3. It is embedded by softening the plastic sheath with a hot soldering iron
4. It is fastened with epoxy resin and sealed with a hot soldering iron

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Learning Objective: Identify techniques of splicing plastic-covered cable for a direct-burial installation.

11-43. All conductors passing through the housing of textbook figure 13-26 are cut and connected to the terminal block.

11-44. What device provides shield continuity in a direct-burial cable that has been brought out of a trench for splicing?

1. Pigtailed conductors
2. Bonding harness
3. Splice housing
4. Terminal block

11-45. What means is used to attach a bonding harness to the cable shield?

1. Hose clamp
2. Tie wire
3. Compression clip

● To answer items 11-46 through 11-49, refer to the splicing procedure of textbook figure 13-31.

11-46. What is done to the loose ends of direct-burial wire after insulation is removed from them?

1. They are twisted together, then placed in solderless wire connectors
2. They are placed into insulated wire connectors, which are then crimped
3. They are placed into split-bolt connectors, which are then tightened securely

11-47. The shield wires of direct-burial are spliced by twisting their loose ends together, pigtailing them, inserting into a solderless wire connector, and twisting into position.

11-48. Why are the conductors and shield wires of direct-burial wire aligned and taped after splicing?

1. To keep moisture out of the splices
2. To insulate the conductors from the shield wires
3. To bundle them for positioning in a mold

11-49. At what point in the procedure for splicing direct-burial wire is the casting compound prepared and poured into a mold?

1. After the conductors and shield wires are bundled, but before they are placed in the mold
2. After the conductors and shield wires are placed in the mold, but before the mold is set into position
3. After the mold is set into position

Learning Objective: Point out techniques of repairing a lead-sheathed cable.

11-50. CE2 Grandle is assigned to repair a deep narrow crack in an aerial cable. The crack extends all the way through the sheath to the insulation. He sets up the splicing platform by the fault in the cable, wirebrushes the section of sheath to be split, and rubs the cable with stearine where he intends to make his cut. In what order does he use his tools as he goes through the procedure for opening the sheath?

1. Small cable stripper blade, large cable stripper blade, small cable stripper blade, cable pliers, wooden wedges
2. Large cable stripper blade, small cable stripper blade, large cable stripper blade, wooden wedges, cable pliers
3. Small cable stripper blade, large cable stripper blade, cable pliers, wooden wedges
4. Large cable stripper blade, small cable stripper blade, cable pliers, wooden wedges

11-51. When soldering closed a seam in a telephone cable sheath, what should you do after the pasters are set?

1. Clean the sheath with a scoring tool
2. Close the sheath so the edges of the cut are 1/4 inch apart
3. Wirebrush the seam
4. Apply stearine to the portion of the seam to be soldered

11-52. A piece of pressboard is put into the opening in a split lead sheath to keep from damaging the cable while the opening is being sealed.

11-53. Which of the following methods is recommended for repairing small ring cuts and cracks in lead sheaths?

1. Wiping with lead
2. Wiping with liquid solder
3. Soldering with a copper
4. Soldering with an acetylene torch

Learning objective: Identify supervisory responsibilities for personnel management.

11-54. Which of the following is NOT a duty of the crew leader for an interior wiring project?

1. Initiating requisitions
2. Keeping time cards
3. Planning work assignments
4. Installing conduit

11-55. Which of the following is NOT a step in the work planning process?

1. Studing plans and specifications
2. Determining the capabilities of the workmen
3. Establishing daily goals
4. Maintaining an approachable attitude

11-56. The purposes of a crew leader's inspection are to teach, guide and direct.

11-57. A supervisor should keep his men informed on all matters that affect them personally.

Learning Objective: Identify principles of requisitioning materials and reporting labor.

11-58. The name and quantity of a requisitioned item are shown in which blocks of NAVSUP Form 1250?

1. No. 3, 4, and 5
2. No. 6, 7, and 8
3. No. 9 and 10
4. No. 13 and 14

11-59. The two categories of total labor for timekeeping and labor-reporting purposes are

1. direct and indirect labor
2. indirect and overhead labor
3. productive and overhead labor
4. productive and direct labor

When answering items 11-60 and 11-61, refer to textbook figures 14-3 and 14-4.

11-60. How many man-hours were spent in training UT2 Johnson's crew on 11 January?

1. One
2. Two
3. Three
4. Four

11-61. How many man-hours did UT2 Johnson's crew contribute to direct labor on 11 January?

1. 10
2. 37
3. 38
4. 48

Assignment 12

Basic Electronic Components and Circuits

Textbook NAVEDTRA 10636-H: Pages 475-505

Learning Objective: Identify fundamentals of coding or rating resistors, capacitors, and chassis wiring.

12-1. Which of the following components would have a measurable effect on the operation of an a-c circuit?

1. Capacitor
2. Inductor
3. Resistor
4. Each of the above

12-2. The power ratings of wire-wound resistors are usually restricted to which, if any, of the following?

1. 1/3 watt
2. 1/2 watt
3. 1 watt
4. None of the above

12-3. What is the lowest possible tolerance of a wire-wound resistor?

1. 1 percent
2. 2 percent
3. 5 percent
4. 10 percent

12-4. A 5,000-ohm composition resistor with a tolerance of 5% will measure between

1. 4,500 ohms to 5,500 ohms
2. 4,750 ohms to 5,250 ohms
3. 5,000 ohms to 5,500 ohms

12-5. The fourth color band on a composition resistor indicates the

1. first significant number
2. second significant number
3. multiplier
4. tolerance

12-6. The third color band on a composition resistor indicates the

1. first significant number
2. second significant number
3. multiplier
4. tolerance

12-7. In a fixed mica capacitor, the color code on the top row is black, orange and gray from left to right, and the bottom row is black, red and orange. What is the value of capacitance?

1. 38 pF
2. 138 pF
3. 380 pF
4. 3800 pF

12-8. A black and yellow lead of a transformer would indicate

1. a tapped primary
2. a tapped secondary
3. the ground wire
4. the high voltage side

In items 12-9 through 12-12, select from column B the color of the chassis wire that is connected to the component in column A.

	A. Components	B. Wire Colors
12-9.	Ground, grounded element, or return	1. Red
		2. Gray
12-10.	Power supply B plus	3. Black
12-11.	Plate	4. Blue
12-12.	A-C power supply	

Learning Objective: Recognize the construction features and operating principles of vacuum tubes and transistors.

12-13. Cathodes are made of materials that emit electrons rapidly.

12-14. Which of the following is the result when the plate of a diode is negative with respect to the cathode?

1. Current flow will be from plate to cathode
2. Tube temperature will increase
3. Tube current will not flow
4. Tube current will increase

12-15. How many ways may a cathode be heated?

1. One
2. Two
3. Three
4. Four

12-16. A tube with two plates and one cathode is called a

1. diode
2. duodiode
3. triode
4. duotriode

12-17. A tube with eight pins on its base is called a

1. duodiode
2. triode
3. duotriode
4. Octal

12-18. How are tube sockets numbered?

1. Clockwise from the key when viewed from bottom
2. Counterclockwise from the key when viewed from the bottom
3. Either 1 or 2 above, depending on the tube envelope size

12-19. The heater or filament of a diode can be destroyed by

1. low voltage
2. excessive current
3. low current

12-20. Current flow through a diode produces a pulsating direct current which can be smoothed out by means of a

1. transformer
2. choke
3. filter
4. center-taped coil

12-21. Which of the following substances is considered the best conductor of electricity?

1. A substance whose orbiting electrons are loosely bound
2. A substance whose orbiting electrons are tightly bound
3. A substance whose electrical charge is zero
4. A substance whose electrical charge is positive

12-22. Which of the following substances is considered the best insulator of electricity?

1. A substance whose orbiting electrons are loosely bound
2. A substance whose orbiting electrons are tightly bound
3. A substance whose electrical charge is zero
4. A substance whose electrical charge is positive

12-23. In the atomic theory of electricity, a hole is defined as the

1. degree of impurity in the nucleus
2. chemical used in making the semiconductor
3. charge of the nucleus
4. vacancy left by an escaped electron

12-24. According to atomic theory, how do holes behave?

1. They move from negative to positive
2. They move from positive to negative
3. They remain stationary

12-25. What is the effect of adding arsenic to a germanium crystal?

1. It increases the number of free electrons
2. It decreases the number of free electrons
3. It increases the number of holes
4. It decreases the number of holes

12-26. In a P-N junction diode, the voltage is said to be in the reverse direction when

1. current flows freely from positive to negative
2. current flows freely from negative to positive
3. the negative lead is on the N material
4. the positive lead is on the N material

● In answering question 12-27, refer to figure 15-17 in the text.

12-27. Where is the reverse bias connected?

1. Between emitter and collector
2. Between emitter and base
3. Between base and collector
4. Across the A battery

● In answering question 12-28, refer to figure 15-18 in the text.

12-28. What is the result of connecting an alternating signal to the emitter-base junction?

1. The current through the emitter-base junction is alternately increased and decreased
2. The current through the base-collector junction is alternately increased and decreased
3. The signal to the load is alternately increased or decreased
4. Each of the above

12-29. Compared with the electron tube, the transistor is a/an

1. large and bulky unit
2. easily damaged component
3. poor source of heat
4. big consumer of electric power

12-30. What is the identification of the case connection in the lower right-hand symbol of textbook figure 15-20?

1. Emitter
2. Base
3. Collector
4. Ground

12-31. When replacing transistors the repairman should always rely on the shape of the replacement to determine connections.

12-32. What is the basic way of connecting a transistor?

1. Common or grounded base
2. Common or grounded emitter
3. Common or grounded collector
4. Each of the above

12-33. What part makes the triode useful as an amplifier?

1. control grid
2. screen grid
3. suppressor grid
4. load resistor

12-34. What is the effect of placing a positive charge on the control grid of a triode?

1. Shuts off plate current
2. Decreases the signal to the tube
3. Increases plate current
4. Increases cathode bias

12-35. What effect, if any, does varying the plate voltage have on the operation of a triode?

1. Causes control grid voltage to vary
2. Causes plate current to vary
3. Shuts off plate current
4. None

12-36. What effect does varying the control-grid voltage have on the operation of a triode?

1. Shuts off plate current
2. Shuts off heater current
3. Causes plate current to vary widely
4. Causes grid current to vary widely

12-37. Which of the following is NOT considered a multielement tube?

1. Tetrode
2. Pentode
3. Triode
4. Each of the above

12-38. Which of the following conditions is true with regard to the screen grid in a tetrode tube?

1. Increases capacitance of the tube
2. Decreases capacitance of the tube
3. Causes tube oscillations
4. Suppresses plate current

12-39. Which of the following conditions is true with regard to the suppressor grid in a pentrode tube?

1. Prevents tube oscillations
2. Is negative with respect to the cathode
3. Is positive with respect to the cathode
4. Is the same potential as the cathode

12-40. Bias obtained from a battery or other constant power source is known as

1. fixed bias
2. self-bias
3. cathode bias
4. grid-leak bias

12-41. What is the function of a grid-leak capacitor?

1. To provide a resonant circuit
2. To leak off excess grid current
3. To apply input signal to the grid
4. Each of the above

12-42. Which of the following best describes cascaded amplifiers?

1. Amplifier stages that are connected in parallel
2. Amplifier stages that are connected in series
3. Amplifiers that are self-biased
4. Amplifiers that are fixed-bias

12-43. Under which of the following conditions would an RC-coupled amplifier be used?

1. When voltage amplification is desired with little or no power output
2. When voltage amplification is desired with a large power output
3. When power amplification is desired with little or no voltage amplification
4. When there is no need to cascade stages

12-44. Which of the following is an advantage of using an impedance-coupled amplifier over an RC-coupled amplifier?

1. Lower supply source required
2. Smaller loss in power
3. Better efficiency
4. Each of the above

12-45. Where are impedance-coupled amplifiers generally found?

1. Last stage power output
2. First stage power input
3. Intermediate frequency stage
4. Power supply unit

12-46. Which of the following is true regarding a transformer-coupled amplifier?

1. Improved frequency is obtained
2. Higher gain is acquired
3. Higher output is not gained
4. Bias voltages are separated between stages

12-47. Connecting the plate of the driver stage to the grid of the driven stage results in a/an

1. single-source biasing
2. inductance-coupled amplifier
3. RC-coupled amplifier
4. directly coupled amplifier

12-48. Which of the following is NOT an advantage of a directly coupled ampliifer?

1. There is no phase distortion
2. There is no voltage supply required
3. There is no loss of frequency response
4. There is a negligible time delay between stages

12-49. Which of the following is an advantage of single-source biasing?

1. Eliminates the need for a separate power supply
2. Provides a built-in heat-sink
3. Provides a higher output/input ratio
4. Provides a higher frequency response

12-50. If a PNP transistor were connected as a common emitter with no signal applied, and the base resistor were to open, it would

1. decrease the amount of forward bias
2. increase the difference in potential between the base and emitter
3. decrease base-emitter current flow
4. cause all signal to be lost

Learning Objective: Recognize principles and techniques of testing electron tubes.

12-51. Prior to inserting a tube in a tube tester, you should

1. allow for sufficient warmup of the the tester
2. be assured that the tube to be tested is defective
3. ensure that controls are set to their proper positions

12-52. To protect the TV-7/U tube tester from damage due to overloads, it is provided with a

1. fuse in series with the transformer primary
2. circuit breaker in series with the transformer primary
3. lamp in series with the transformer primary
4. fuse in series with the transformer secondary

12-53. When a vacuum tube is being tested with the TV-7/U tube tester and both plates of the neon lamp glow, what, if anything, is indicated?

1. A normal condition
2. A short-circuited tube
3. A gassy tube
4. Nothing

12-54. When performing a gas test on a vacuum tube, you shift switch S from position 1 to position 2, and no change occurs in the meter reading. What, if anything, is indicated?

1. A normal condition
2. A shorted tube
3. A gassy tube
4. Nothing

12-55. If a tube under test develops noise, what condition can be safely assumed?

1. The grid has a positive bias
2. The tube is gassy
3. A short exists between cathode and heater
4. An open exists between cathode and suppressor grid

12-56. What is the purpose of conducting the filament activity test on an electron tube?

1. Estimate the remaining useful life of the tube
2. Determine the number of short-circuited tube elements, if any
3. Check for the presence of a leakage path between the cathode sleeve and heater wire
4. Check for the presence of gas in the tube envelope

12-57. To perform an Ico test on a transistor using a TS-1100/U, it is necessary to

1. remove the transistor from the circuit
2. leave the transistor in the circuit
3. test with multimeter first

12-58. Which of the following is a safe practice in testing a transistor with a multimeter?

1. Remove the transistor from the circuit
2. Leave the transistor in the circuit
3. Ensure meter sensitivity is at least 10,000 ohms per volt
4. Ensure meter input resistance is at least 5 megohms

12-59. When testing transistors with a multimeter, you should exercise care to ensure that internal voltage does NOT exceed 6 volts.

12-60. Which of the following is a safe practice in testing a circuit containing transistors?

1. Short circuit the transistors
2. Discharge all capicators in the test circuit
3. Use an ohmmeter which passes more than 1 milliampere through the test circuit
4. Use a multimeter with same impedance

12-61. When performing a leakage test, you should replace the transistor if the leakage current is less than or equal to the allowable current.

12-62. The transistor test set TS-1100/U eliminates interference from direct currents in transistor circuits by

1. shorting all transistors
2. shorting all capacitors
3. testing with alternating current
4. utilizing an oscillator

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